RT-Range

Lane position and vehicle-to-vehicle measurement

User Manual

Covers all RT-Range models

Confidently. Accurately.

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Introduction

The RT-Range is a bolt-on system to the RT inertial and GNSS navigation system that performs two tasks:

1. It measures the position of a vehicle relative to lane markings.

2. It measures the relative position, i.e. range, between multiple vehicles.

The lane position feature of the RT-Range is useful for testing and validating other technologies for lane position measurement, such as lasers or vision. The range or distance between multiple vehicles is useful for validating cruise control radar and other advanced accident avoidance systems.

The RT-Range is designed to be used with the RT series of products (100 Hz and 250 Hz). The output rate of the RT-Range is determined by the output rate of the RT in the hunter vehicle.

Following a redesign of the RT-Range housing and vehicle-to-vehicle communication hardware, the latest version of the RT-Range is now called the RT-Range S. The RT-Range S is essentially the same as the standard version, but has been re-designed with more robust internal and external connections and uses the RT-XLAN as the preferred method of vehicle-to-vehicle data communication rather than the internal WLANs in the previous design. The use of the RT-XLAN device in the new design will provide a far greater communication range than previously possible.

Throughout the manual there are references to the RT3000. These apply equally to other RT products as well, unless stated otherwise. There will also be references to RT-Range accessories, cables and connections, which may be slightly different depending on whether you have an RT-Range or RT-Range S.

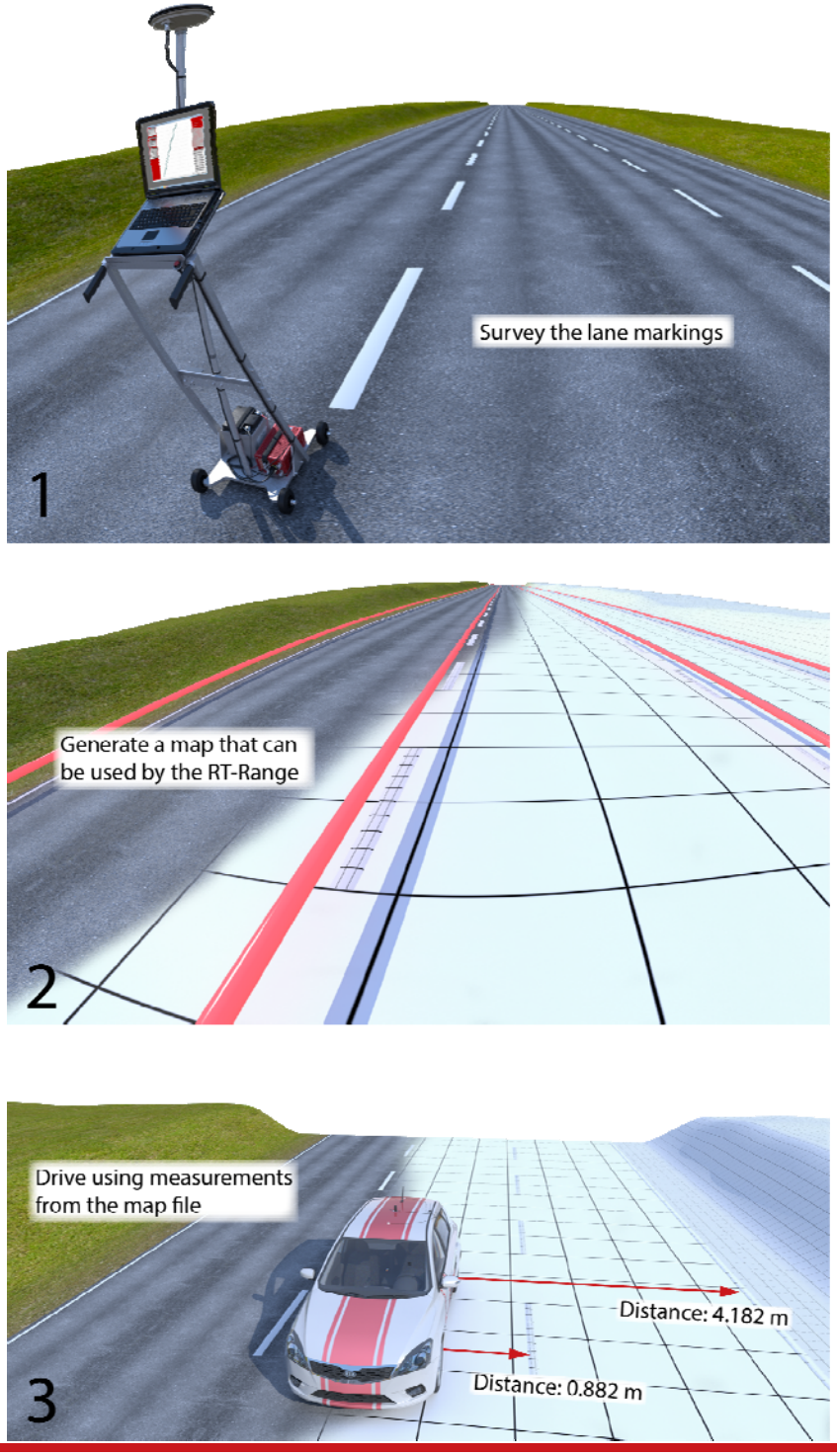
RT-Range software version 141216 (reverse date format) and onwards allow the RT-Range to become a fully featured CAN acquisition system, displaying and logging real-time CAN data from multiple sources within each vehicle alongside RT-Range data. This feature can significantly reduce the complexity of the data collection process. Its use for CAN data is dependent on the RT in the relevant vehicles having the CAN acquisition feature enabled. Please contact OxTS or your local representative for more information.

Lane position methodology

Lane position is measured by surveying the road markings using an RT system and generating a map from the data. The RT system is then fitted to the car and the map is downloaded to the RT-Range. The RT-Range compares the current position reported

by the RT to the map. The lane position measurements are output over Ethernet and CAN bus. See Figure 1 for details of these steps.

Figure 1. Steps taken for Lane Position Measurement in RT-Range



The RT-Range allows up to eight lane markings to be measured. In addition, the RT-Range provides three separate measurement points on the vehicle and gives the distances from these three points to the lane markings. As well as distance, the RT-Range measures velocity and acceleration relative to the lane markings. To help plot the data, the RT-Range also gives the distance travelled along the reference line (Line 1).

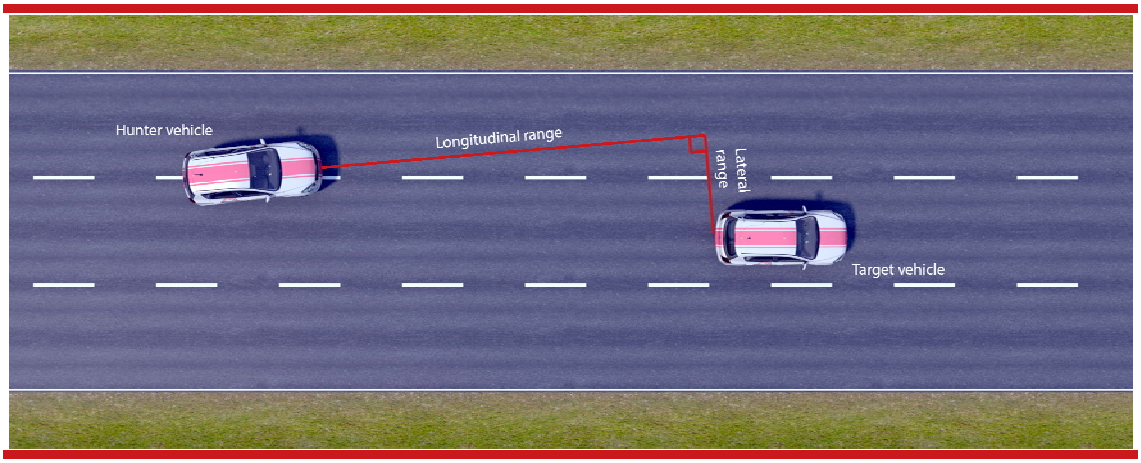
Distance between multiple vehicles methodology

Calculating the distance between multiple vehicles requires an RT system to be installed in each vehicle. Distance measurements are made from the hunter vehicle to each target. The measurements are in the reference frame of the hunter vehicle, so a longitudinal, lateral and resultant range can be measured. The RT-Range supports up to four mobile targets.

The measurements made by the RT fitted in each target vehicle are transmitted wirelessly back to the hunter vehicle by high speed Wireless LAN. The RT-Range receives those measurements and computes the distances, velocities, accelerations and other parameters about the vehicles. To allow for radio delays, the RT-Range predicts the position of each target vehicle so the measurements can be output in real-time with a low latency. The RT-Range can also operate with a fixed delay, so as to give the radio time to transmit the data and reduce the error in the prediction. The effect of prediction is discussed later.

Typically the radio delay is 10 ms and there is no degradation in performance with this delay. Even when the radio delay is up to 50 ms, the error in range is very small (less than one centimetre).

Figure 2. Range measurements between two vehicles



The measurement points on the hunter vehicle and on the target vehicles can be different to the position of the RTs and different to the positions of the lane measurement positions. This makes it easy to compare the RT-Range measurements to those of a radar mounted on the front of the car. The target vehicles can be represented as polygons and the hunter will then track the closest point on the polygon's perimeter, including interpolating between the polygon points.

Distance to fixed points and feature points methodology

Just as the RT-Range measures the distance to a mobile target (another vehicle or pedestrian), it can also measure the distance to a fixed point (e.g. a balloon car). The RT-Range includes tools to measure the position of fixed points accurately and quickly.

The RT-Range can also recognise feature points. Feature points are a large collection of fixed points representing signs, road markings and other street furniture at known positions. Unlike fixed points, which are active all the time, a field of view can be defined in the RT-Range to represent a camera. When feature points enter the "camera's" field of view, the distance to those feature points can be computed. For example, along a test route on the public highway, the position and classification of 10,000 feature points is known; as the vehicle drives along the route, the RT-Range will output the distance to the feature points that are currently in view.

ABD robot connection

The RT-Range can provide feedback to the ABD steering robot. This allows the robot to trigger tests based on distance measurements, which is useful for repeatability in Adaptive Cruise Control (ACC) tests. Other Advanced Driver Assistance System (ADAS) tests also benefit from having the ABD robot triggered by distance measurements. The ABD robot software can also acquire measurements from the RT-Range and merge it with robot data.

RT-Backpack for pedestrians

The RT-Backpack is designed to work with the RT-Range. It is a target system in a backpack that can be carried by a pedestrian. The RT-Backpack transmits all the signals to the hunter vehicle in the same way as vehicle-based mobile target. The RT-Backpack is designed to be used with the RT2000, RT3000 or RT4000 products, which are fitted in to the RT-Backpack.

Outputs

The RT-Range outputs its data over Ethernet and over CAN bus in real-time. The Ethernet values can be picked up by the RT-Range software and displayed on a PC.

Target CAN

The navigation CAN messages from target vehicles are output by the RT-Range Hunter. This allows the acquisition system in the hunter vehicle to collect all of the measurements from the hunter vehicle *and* the target vehicles together.

Note that the CAN bus will be overloaded if all the messages from all of the vehicles are put on the CAN bus at one time. The RT-Range software can select the CAN messages and the data rates for all the messages that are put on to the bus.

Scope of Delivery

The RT-Range consists of several different sections, these are broken down into:

1. Hunter vehicle components
2. Target vehicle components
3. Survey Trolley and accessories (optional)

A separate table has been made for each section.

In addition to these components an RT (RT2000, RT3000 or RT4000) system is required. Please see the RT manual for the components in an RT system.

Table 1. RT-Range S Hunter vehicle components

Item	Qty.	Description
1	1	RT-Range S Hunter system unit
2	1	Power cable M12(M) to M12(F) - 14C140A
3	1	Power cable M12(F) to cigarette lighter plug - 77C0002B
4	1	RJ45-RJ45 2 m Ethernet cable (UDP straight)
-	1	RT-Range Manual
-	1	RT-Range Software CD

Figure 3. Image of RT-Range S Hunter with components

Note: The RT-Range S components differ slightly from the standard RT-Range system.

Table 2. RT-Range S Target vehicle components

Item	Qty.	Description
1	1	RT-Range S target system unit
2	1	Power cable M12(M) to M12(F) - 14C140A
3	1	Power cable M12(F) to cigarette lighter plug - 77C0002B
4	1	RJ45-RJ45 2 m Ethernet cable (UDP straight)
-	1	RT-Range Manual
-	1	RT-Range Software CD

Figure 4. Image of RT-Range S target with components

Note: The RT-Range S components differ slightly from the standard RT-Range system.

Table 3. RT-Range Survey Trolley components

Item	Qty.	Description
1	1	Base plate with wheels attached
1	2	Lower frame assembly with radio antenna plate attached
1	3	Upper frame assembly
1	4	Fixed PC shelf
3	5	Antenna pole sections
1	11	GPS-702-GG antenna
2	6	Joint alugs
12	7	M6 × 12 mm hex socket screws
12	8	M6 washers
4	13	M4 × 40 mm countersunk bolt with locking nuts
4	12	M4 nuts
4	14	M4 washers
1	9	UNC bolt
2	10	1” U-Bolt with plate and nuts
2	15	Bungee straps
1	16	Battery connection cable
1		Battery charger
1		Mains cable
1		Trigger switch

Note: Some of these components might already be pre-assembled on delivery. Item numbers refer to the assembly drawing in Figure 12.

Battery

The Survey Trolley will require a battery. Please note that this is not supplied by OxTS and must be purchased by the customer. The ideal battery is a Yuasa NP24-12, a 12 V, 24 Ah lead acid battery measuring 166 × 175 × 125 mm.

Figure 5. Survey Trolley

Specification

The technical specification of the RT-Range depends on both the type of wireless LAN communication link and RT systems being used.

We recommend the use of the RT-XLAN on the RT-Range. Using the RT-XLAN will make it possible to achieve longitudinal ranges in of around 1 km and will improve the data integrity at the lower ranges. However, its use does depend on your location and the local wireless LAN radio laws governing your particular area for suitability. If you are unsure please contact your local representative for advice.

The RT systems we recommend using are the RT3002, RT3003 or RT2002; these all provide 1–2 cm positioning accuracy depending on the model. If a 250 Hz output rate is required, use an RT4002 or RT4003 series product. The RT-Range can work with lower accuracy and lower cost RT systems, which may be acceptable in long range applications where accuracy is less important.

Table 4. Technical specification for RT-Range S system

Parameter	Specification
Voltage	10–25 V dc
Power	15 W
RT-Range S Dimensions	234 × 120 × 76 mm
Mass	1.93 kg (Hunter) 1.60 kg (Target)
Operational temperature	-10 to 50°C

Table 5. Technical specification for lane measurements

Parameter	Range	Accuracy using RT3002
Lateral distance to lane	±30 m	0.02 m RMS
Lateral velocity to lane	±20 m/s	0.02 m/s RMS
Lateral acceleration to lane	±30 m	0.1 m/s ² RMS

To achieve these accuracies it is necessary to construct the map correctly. See the Calculation details section. It is also essential to configure the RT and the RT-Range correctly. It is not easy to measure all of the parameters accurately, but time must be taken to do this.

Table 6. Technical specification for RT-Range with RT-XLAN

Parameter	Specification
RT-XLAN radio range	Approx. 1 km line of sight
RT-XLAN Delay	<50 ms RMS

Note: These figures are based on a correctly configured RT-XLAN system.

Table 7. Technical specification for RT-Range with standard wireless LAN

Parameter	Specification
Wireless LAN radio range	Approx. 200 m line of sight
Wireless LAN Delay	<70 ms RMS

Note: These figures are based on a typical wireless LAN device such as those used in the original RT-Range system.

Table 8.Technical specification for range measurements - RT-XLAN

Parameter	Range	2 × RT3002
Longitudinal Range	±1 km	0.03 m RMS*
Lateral Range	±1 km	0.03 m RMS*
Resulting Range	±1 km	0.03 m RMS*

* Note: There is an additional component, the heading accuracy, which changes the accuracy of the measurements in the hunter vehicle's co-ordinate frame. In a scenario where the target is ahead or behind the hunter i.e. approximately 0 or 180 relative heading, then the Lateral Range has an additional error of Range × 0.00175 (as a result of the 0.1 deg heading accuracy). So for example at a range of 100 m then the lateral accuracy is 0.175 m, and for 1000 m the lateral accuracy is 1.75 m. However for a scenario where the vehicles are adjacent, the situation is reversed so the Lateral Range accuracy is 0.03 m RMS and the Longitudinal Range accuracy is 0.00175 × Range RMS.

Table 9.Technical specification for range measurements - standard wireless LAN

Parameter	Range	2 × RT3002
Longitudinal Range	±200 m	0.03 m RMS*
Lateral Range	±200 m	0.00175 × Range RMS*
Resulting Range	±200 m	0.03 m RMS*

* Note: In this example all details are the same as the Note of Table 8, except that for 200 m the lateral accuracy is 0.35 m.

Note: If you use alternative wireless LAN devices, you should not expect to achieve the kind of ranges possible with the RT-XLAN. Wireless LAN is also affected by high power electrical fields such as those found under high voltage electricity pylons.

Warranty

Oxford Technical Solutions Limited warrants its products to be free of defects in materials and workmanship, subject to the conditions set forth below, for a period of one year from the Date of Sale.

'Date of Sale' shall mean the date of the Oxford Technical Solutions Limited invoice issued on delivery of the product. The responsibility of Oxford Technical Solutions Limited in respect of this warranty is limited solely to product replacement or product repair at an authorised location only. Determination of replacement or repair will be made by Oxford Technical Solutions Limited personnel or by personnel expressly authorised by Oxford Technical Solutions Limited for this purpose.

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Conformance notices

The RT-Range S complies with the radiated emission limits for 47CFR15.109:2014 class A of Part 15 subpart B of the FCC rules, and with the emission and immunity limits for class A of EN 55022. These limits are designed to provide reasonable protection against harmful interference in business, commercial and industrial uses. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following:

- Re-orient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.

The RT-Range S conforms to the requirements for CE.

Regulator testing standards

- FCC rules , Title 47 CFR (March 2014), Part 15.109, Class A limits
- EN 55022:2010
- EN 55024:2010
- EN 61326-2-1:2006 using the general requirements of EN 61326-1:2006
- EN 61326-1-1:2013 using the general requirements of EN 61326-1:2013

Installation

The installation of the RT-Range assumes that the RT systems have already been installed correctly in the vehicle. It also assumes that you have an RT-Range S system with an RT-XLAN vehicle-to-vehicle communication device. If you have a standard RT-Range system then the wiring is similar to that shown here except that it uses a standard WLAN integrated into the RT-Range case.

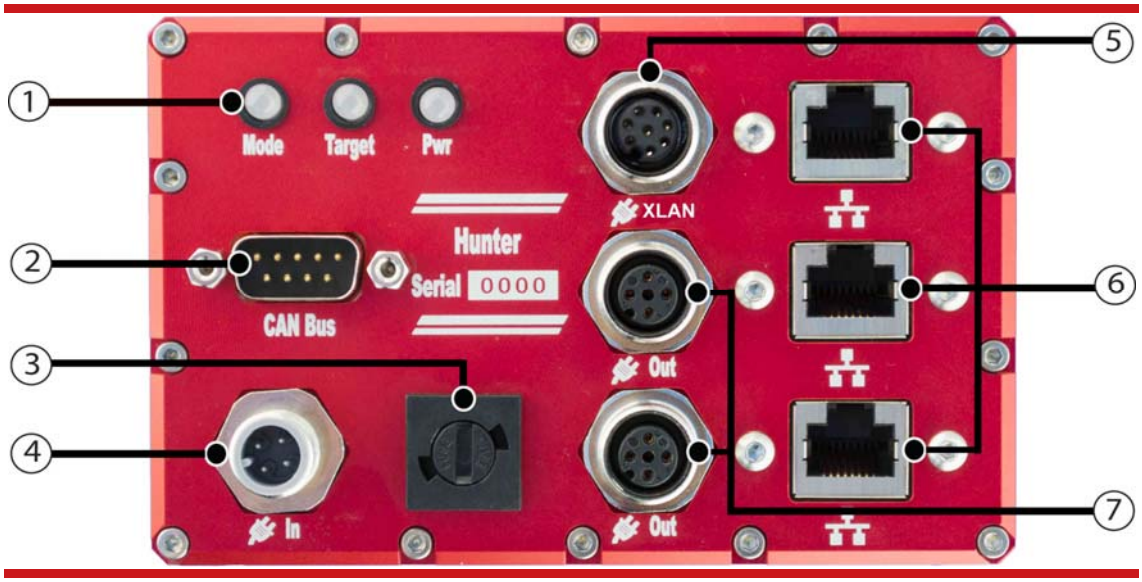
It is possible to use the RT-XLAN with the standard RT-Range system or directly to the RT in the target vehicle and this is described in the RT-XLAN manual.

Please contact support@oxts.com if further wiring or configuration advice is required.

RT-Range S connections

The RT-Range S Hunter front panel connections are shown in Figure 6, please refer to Table 10 for a description of each item.

Figure 6. RT-Range S front panel layout



The RT-Range S target front panel is very similar to the hunter, but only has one LED for power and does not have a CAN output.

Table 10. RT-Range S front panel layout descriptions

Label	Item	Description
1	LEDs	These have various definitions and are described in the *LED definitions* section of this manual
2	CAN out *(Hunter only)*	Requires 120 Ω resistor between CAN High and CAN Low and is described in the *CAN Bus* section of this manual.
3	Fuse	Fitted with a 4 A quick blow fuse
4	12 V Power in	10–25 V dc power input
5	RT-XLAN PoE	Dedicated PoE port. Provides Ethernet and power to the RT-XLAN
6	Ethernet ports	Built in 3 port Ethernet switch
7	12 V Power out	2 × 12 volt power output sockets for an RT and a spare

LED definitions

It is best to use the RT-Range software for detailed information about the status of RT-Range S system, but the LEDs on the front panel are capable of giving a quick indication of the status of the system.

Mode (Hunter only). Indicates how the RT-Range is configured. When it is configured to make vehicle-to-lane and vehicle-to-target measurements the LED will be orange. When configured to make just vehicle-to-target measurements the LED will be red. For lane only measurements the LED will be green. A solid LED indicates no data is coming from the hunter. A flashing LED indicates the hunter is outputting data.

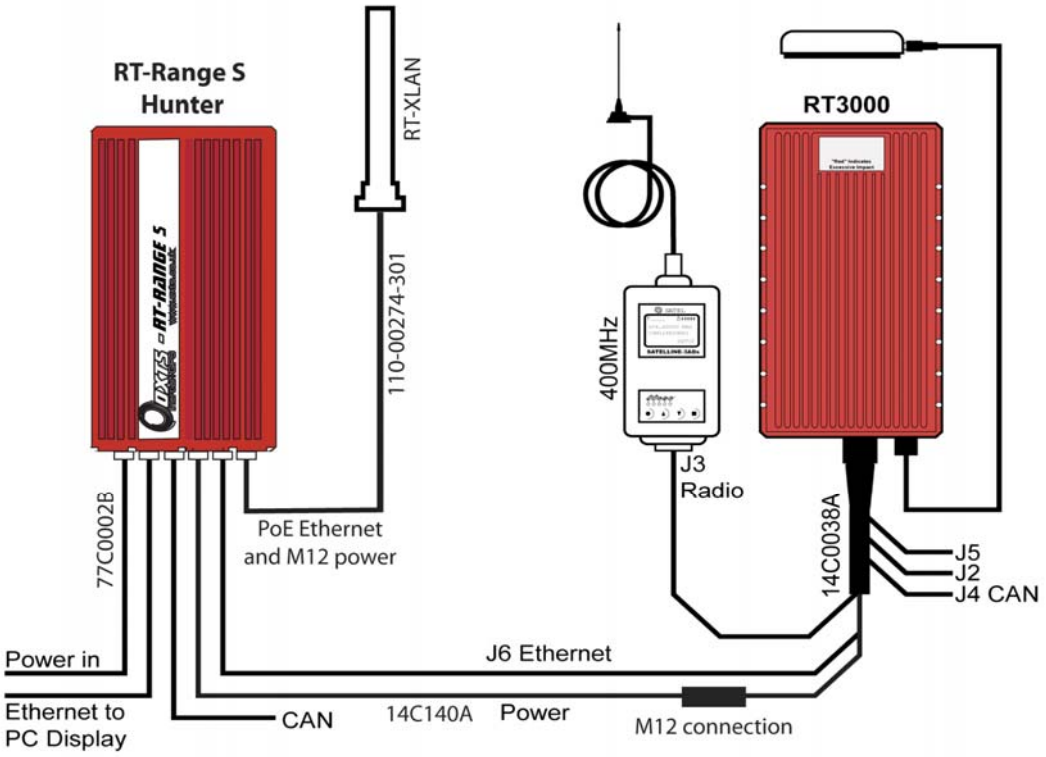
Target (Hunter only). Indicates data is being received over Ethernet from target 1. This LED should always be flashing red. A solid LED, Orange or Green colour indicates a fault.

Power (Hunter and Target). Unit is powered up when lit.

Hunter vehicle wiring

The wiring diagram for the hunter vehicle is shown in Figure 7.

Figure 7. Wiring diagram for RT-Range S Hunter vehicle



Where an RT2500 or RT2002 is used, the wiring is the same as above except that the J6 Ethernet in the 14C0038A user cable is replaced with a straight Ethernet patch cable and is connected directly to front panel of the RT2000 along with the 14C140A power cable.
A switch or trigger can be connected to J5 and used to trigger logging in the RT-Range PC software.

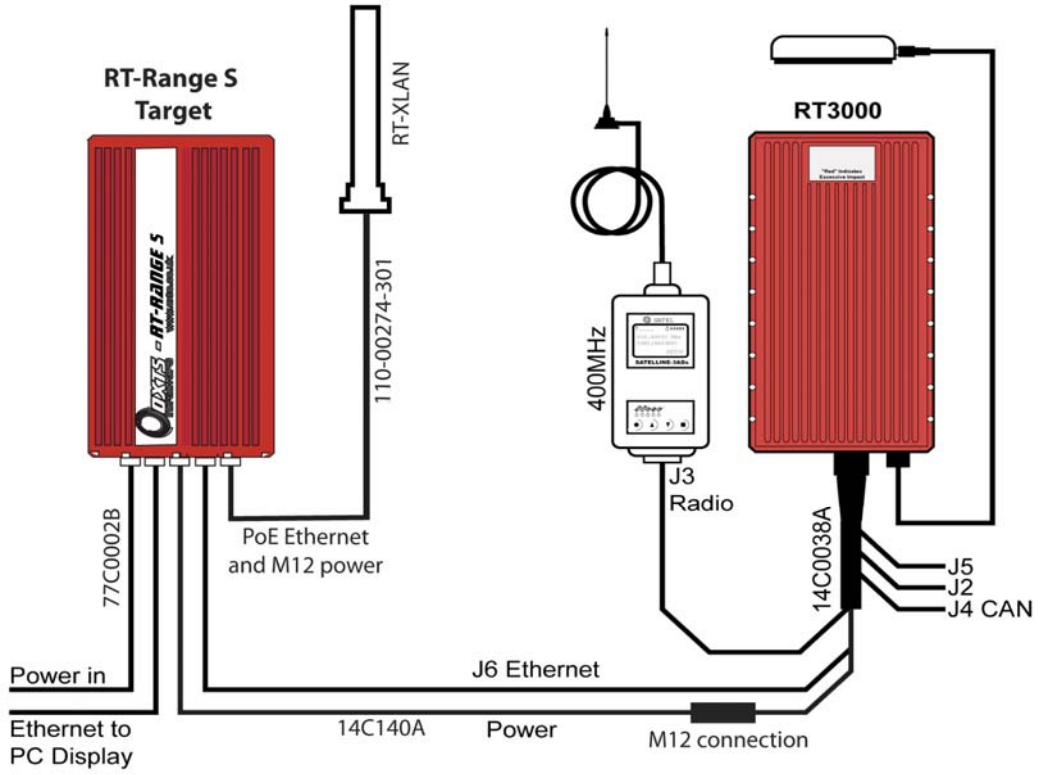
If the Ethernet cable on the RT user cable is too short then it can be extended.

The RT-XLAN is connected to the RT-Range S Hunter using the Power over Ethernet (PoE) cable 110-00274-301 provided with the RT-XLAN. It is important that only this cable is used or there may be problems powering up the RT XLAN.

Target vehicle wiring

The wiring diagram for the target vehicle is shown in Figure 8

Figure 8. Wiring diagram for RT-Range S Target vehicle



Where an RT2500 or RT2002 is used, the wiring is the same as above except that the J6 Ethernet in the 14C0038A user cable is replaced with a straight Ethernet patch cable and is connected directly to front panel of the RT2000 along with the 14C140A power cable.
A switch or trigger can be connected to J5 and used to trigger logging in the RT-Range PC software.

If the Ethernet cable on the RT user cable is too short then it can be extended.

The RT-XLAN is connected to the RT-Range S Target using the Power over Ethernet (PoE) cable 110-00274-301 provided with the RT-XLAN. It is important that only this cable is used or there may be problems powering up the RT-XLAN.

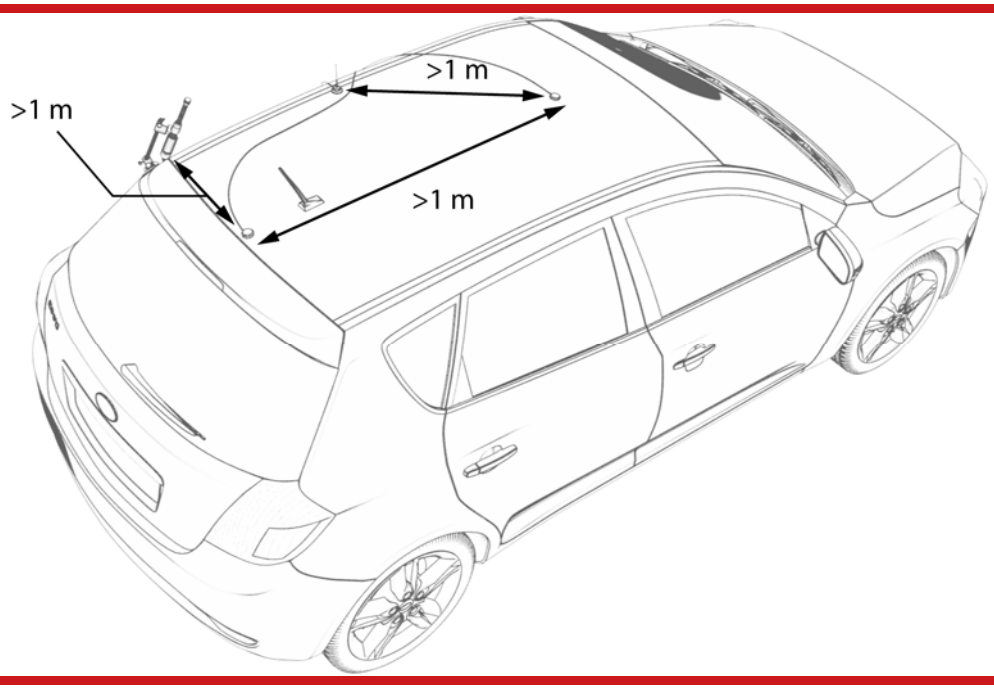
By using an RT-XLAN Y cable converter kit (available from OxTS) it is possible to connect the RT-XLAN directly to the RT in the target vehicle avoiding the use of the RT-Range S Target unit where no other connectivity is required. More information about this can be found in the RT-XLAN manual.

Physical Installation

The antennas for the radio, RT (GNSS) and the RT-XLAN or standard Wireless LAN mag mount antenna should be spaced out across the roof of the vehicle. Putting all the antennas in one spot will cause interference and will reduce the performance of the system. Ideally there should be at least a 1 m separation between each antenna. In

addition, the cables for the antennas should not be routed together since this can also cause interference.

Figure 9. Ideal antenna locations on top of the vehicle



The position where the RT is installed in the vehicle is not critical for the accuracy of the RT measurements. However, normally the user requires the RT to be located at a specific position such as the centre of gravity. The RT-Range configuration includes configurations for the positions of the RT-Range measurements, so these are remote from the RT mounting position. See the section on the RT-Range software for more information on configuring the measurement positions.

The RT-Range S Hunter and Target boxes are suitable for mounting on the RT-Strut with the RT. If you have the standard RT-Range Hunter and Target boxes, these are a suitable size for positioning behind the passenger seat.

CAN Bus

Cables for the CAN bus will need to be prepared by the user. Because the CAN bus can have many devices or *nodes* on it, it is impossible to supply a suitable cable for all circumstances.

When preparing the cable it is essential to put in at least one 120 Ω resistor between CAN High and CAN Low. Again, this is a feature of the CAN bus and not of the nodes on the CAN bus. Although CAN is a differential bus and does not require the ground to

be connected, many systems will not work unless the ground is connected. You are advised to always connect the grounds of the systems.

See the cable drawings for details of the connections required for the CAN bus.

RT Configuration

Full instructions on how to configure the RT are supplied in the RT User Manual. Only the settings applicable to the RT-Range are listed here.

The RT-Range and the RT both have the ability to displace the measurements to a remote position. If the RT has a displaced output then the RT-Range will work from this displaced output position and not from the mounting location of the RT. In other words, the RT's output displacement will displace *all* of the measurement points of the RT-Range.

For simplicity you are advised to disable the Output Displacement option of the RT systems and only use the output displacement options of the RT-Range.

The CAN baud rate for the RT-Range, the RT and for the other nodes on the CAN bus must be the same.

The performance of the wireless LAN can be improved by delaying the Ethernet output of some of the RTs. Normally each target is delayed by a different amount so that their output on the wireless LAN does not clash. This can be configured on the Ethernet option of NAVconfig.

RT Processing Platform

Only the latest "TP500" and "TP600" processing platforms can work with 250 Hz products or in installations where there are 4 targets. The older platforms, such as the TP400, do not have sufficient processing power and will give incorrect results. The following FAQ describes how to find which processing platform is in an RT system:

http://support.oxts.com/faqs/topic/how-can-i-check-what-model-of-processor-card-is-fitted-in-my-unit/

IP Addresses

The RT-Range and the RTs communicate using TCP/IP. If some of the RTs have the same IP address then it will be necessary to change the IP addresses so that they do not clash. The RT-Range will identify which RT is performing each task by the IP address of the relevant RT. You must not have two (or more) devices on the same network with the same IP address.

Each RT has a static IP address. This is normally in the range 195.0.0.10 to 195.0.0.99. Some early systems are not in this range.

The RT-Range Hunter has its own IP address. This is normally in the range 195.0.0.110 to 195.0.0.120. Again, some really early systems are not in this range.

The IP configurations of the wireless LAN devices used for vehicle-to-vehicle communication will vary depending on whether you have an RT-Range S with RT-XLAN or the standard RT-Range system. The differences are shown in Figure 10 and Figure 11.

The RT-Range S system can be used with other types of wireless LAN devices if required. For configuration, you should follow the basic examples shown in this manual while referring to the guidelines of the relevant manual for the wireless LAN device you are using.

RT-Range S system

For the purposes of this illustration, the manual will refer to the RT-XLAN for configuration of the RT-Range S system.

The RT-XLAN will normally be factory configured as follows:

- RT-XLAN Base [Hunter]: 195.0.0.170
- RT-XLAN Client [Target 1,2,3,4]: In the range of 195.0.0.171 to 195.0.0.174

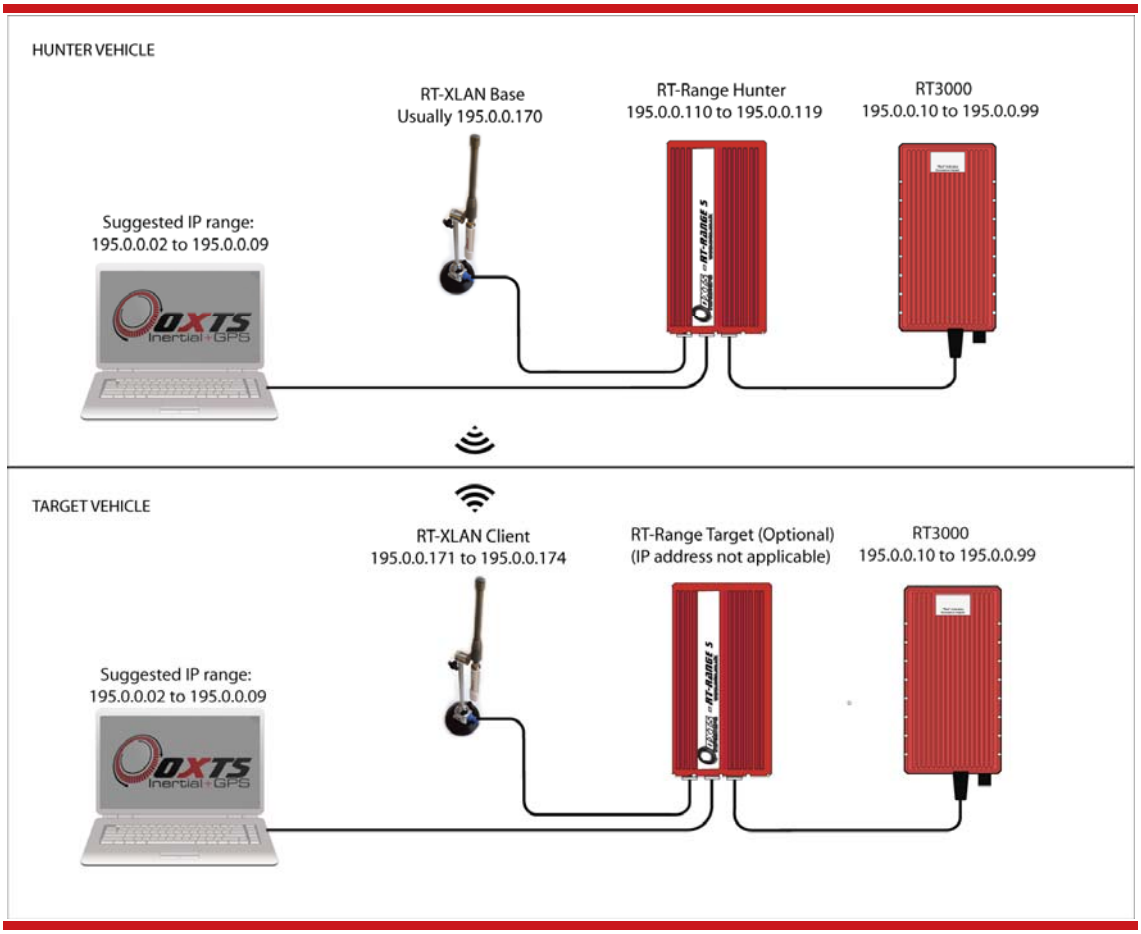
Each RT-XLAN will be marked showing its IP address and configuration. This may be especially useful if you have ordered different IP addresses to the standard ones.

For more information about the RT-XLAN configuration please refer to the RT-XLAN user manual.

For alternative wireless LAN devices, the “Base” should be configured as an “Access Point” in “network bridge” mode, and the “Client” should be configured as a “station” in “network bridge” mode. There may be variations to this for different wireless LAN devices and we recommend speaking to the WLAN device manufacturer, asking them for the best way to achieve a Base - Client configuration as specified above.

A typical IP configuration of an RT-Range S system is shown in Figure 10.

Figure 10. IP address ranges–RT-Range S system

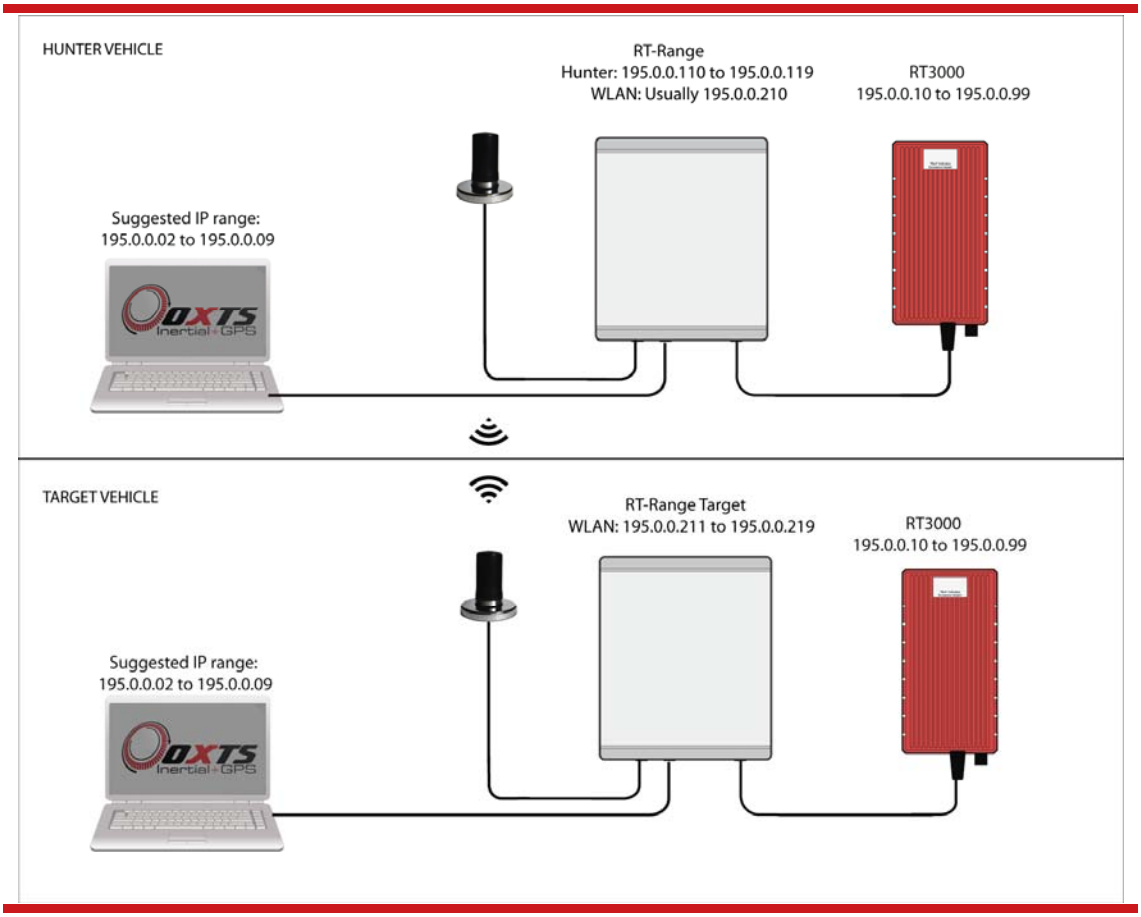


Standard RT-Range system

The RT-Range Hunter wireless LAN is normally configured as 195.0.0.210. The RT-Range Target wireless LAN is normally configured in the range 195.0.0.211 to 195.0.0.219. With multiple targets it is likely that you will need to change the IP address of the wireless LANs.

A typical IP configuration of a standard RT-Range system is shown in Figure 11

Figure 11. IP address ranges–standard RT-Range system



If the wireless LANs are configured in Ad Hoc mode and more than one RT-Range Hunter is being used in the same area then the RT-Range Hunters will be required to have different IP addresses. In Access Point/Client mode the SSID of one of the groups will need to be changed or the Wireless LAN Access Points will clash.

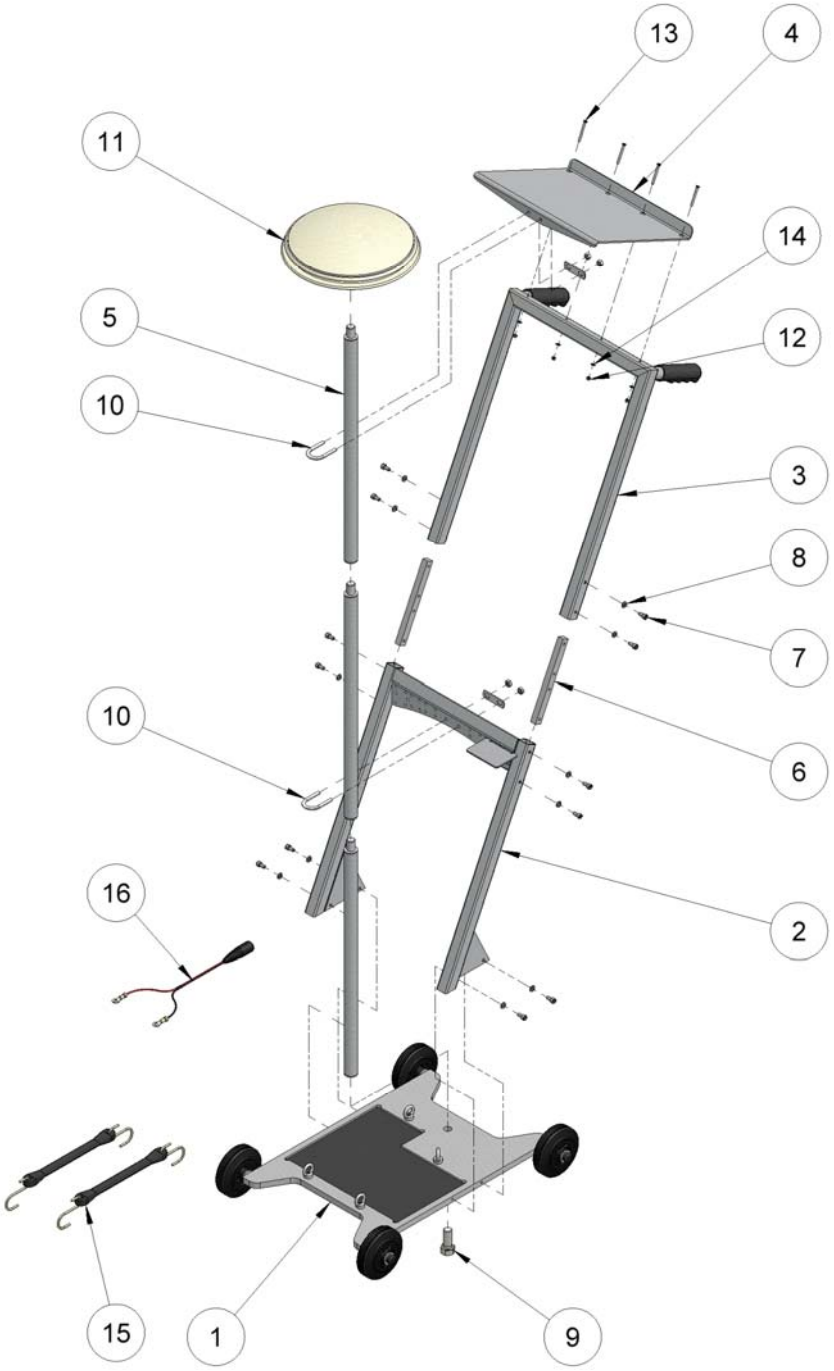
It is possible to use alternative wireless LANs like the RT-XLAN on the standard RT-Range systems provided they are configured correctly. The configuration is similar to the RT-Range S and this is shown in Figure 10. Please contact support@oxts.com if you require further advice on how to do this.

Survey Trolley Assembly

The Survey Trolley is shipped partially assembled. Figure 12 is an exploded view showing how to assemble the survey trolley.

Table 3 lists the numbered parts.

Figure 12. Survey Trolley assembly



Survey Trolley installation

The survey trolley has been designed to carry the RT, a battery and a laptop computer. The GPS antenna on the survey trolley is sufficiently high so that there will be minimal interference from the operator. The position measurements are displaced to the front

right wheel so that this wheel can be pushed along the road markings. The displacement will be accurate even when the survey trolley is at a significant angle (e.g. on a road with a large camber.

The RT should be set up on the survey trolley facing the rear and clamped down securely so it cannot move. The installation on the survey trolley is shown in Figure 13.

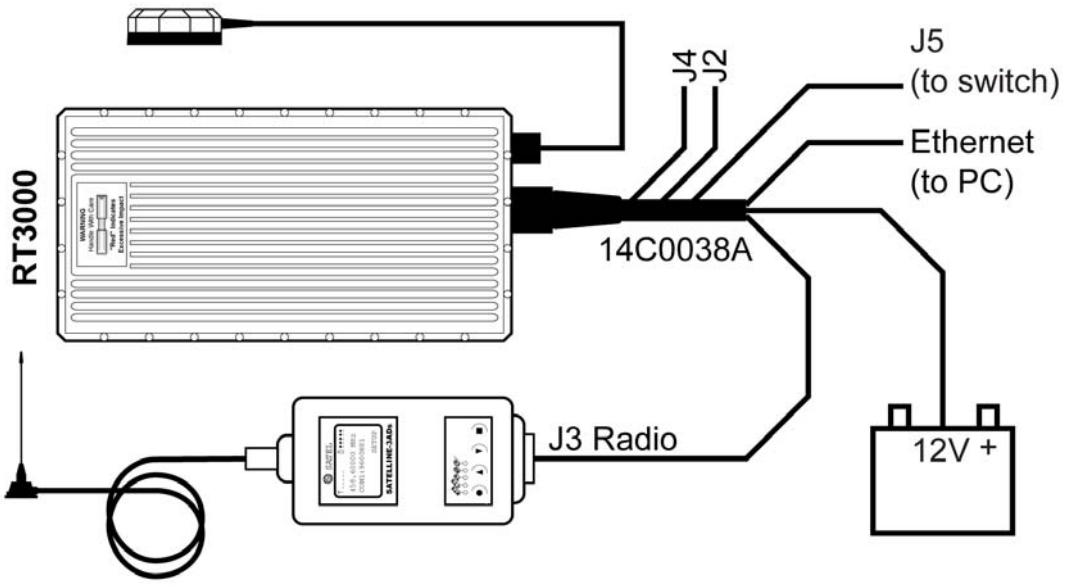
Figure 13. Survey Trolley installation

An iron plate is provided to hold the magnetic antenna for the radio modem.

The connections for the RT on the survey trolley are the same as those on a vehicle and are shown in Figure 14.

If a trigger switch is being used then it should be connected to J5 of the RT. A trigger event can be made by shorting the Event Input pin on J5 of the 14C0038A User Cable to ground. The trigger event can be used to place a point in the line file for the map. A switch is provided with the survey trolley with a pre-wired connector that fits on J5.

Figure 14. Connection diagram for the RT on the Survey Trolley



Note: The connection is shown here with the SATEL radio option. The Freewave and other radio options are similar.

The RT will need to be configured correctly for use on the Survey Trolley. Table 11 lists the critical configuration parameters that should be used with the Survey Trolley. Other parameters can be left at the default values.

Table 11. RT Configuration on the Survey Trolley

Parameter	Setting
Orientation	Default settings: *y*-axis right; *z*-axis down.
Primary Antenna	Behind 0.230; left 0.075; above 1.520; overall accuracy 0.01
Dual Antenna	No
Initialisation Speed	1 m/s
Displace Output	Ahead 0.125; right 0.105; below 0.095

This configuration sets the measurement point for the survey at the centre of the wheel contact patch for the front right wheel of the survey trolley. It is normally easier to survey using a wheel as a marker rather than a point on the survey trolley.

A suitable configuration for the Survey Trolley is installed in the folder:

C:\Program Files (x86)\OxTS\RT-Range\Survey Trolley

This can be installed using NAVconfig.

To initialise the RT on the Survey Trolley push the Survey Trolley in a forward direction at a speed exceeding 1 m/s. You should be going straight when the RT initialises. Afterwards you should make some turns, accelerate and brake so that the RT can estimate some of the errors in its sensors.

The battery recommended for use with the Survey Trolley is a lead-acid battery. This should be kept in a charged state; it should be recharged immediately after each use. Lead-acid batteries tend to degrade if left in an uncharged state.

To charge the battery, connect the charger to the battery and plug the charger into the mains. The light on the charger will indicate green when the battery is fully charged. The charger can be left on the battery at all times when the battery is not in use.

Lead-acid batteries require special disposal in most countries. To dispose of the battery take it to the appropriate waste disposal place.

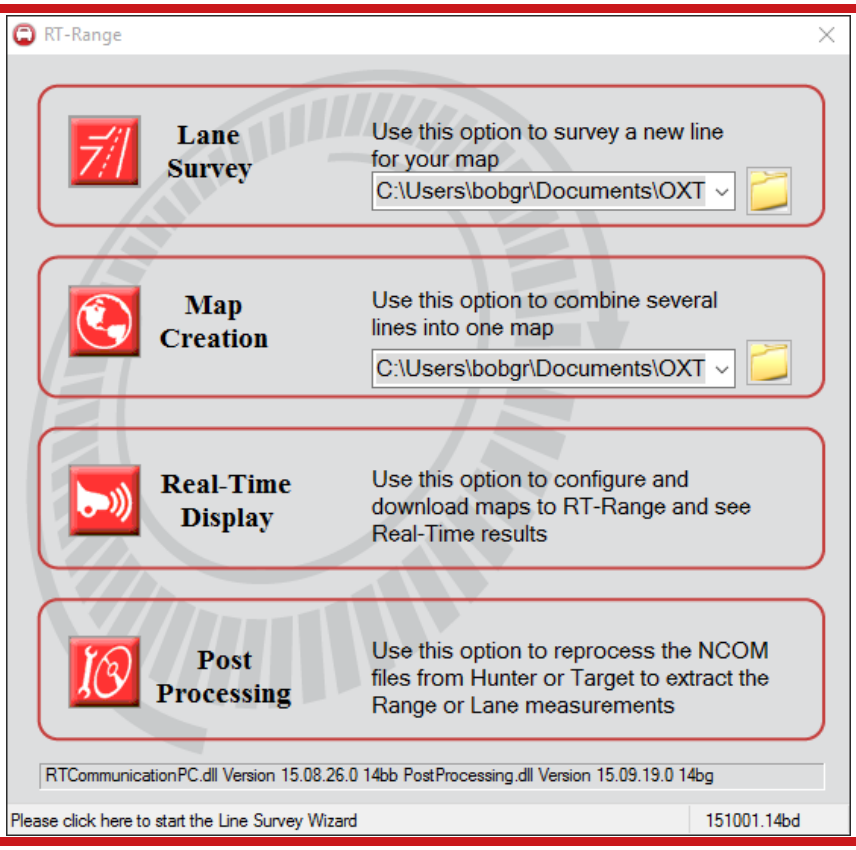
Software

RT-Range Software consists of four modules. These are:

1. Lane Survey
2. Map Creation
3. Real-Time Display
4. Post Processing

Figure 15 shows the Initial Page of the RT-Range Software.

Figure 15. Initial page of RT-Range software


RT-Range
Lane Survey
Use this option to survey a new line for your map
C:\Users\bobgr\Documents\OXT
Map Creation
Use this option to combine several lines into one map
C:\Users\bobgr\Documents\OXT
Real-Time Display
Use this option to configure and download maps to RT-Range and see Real-Time results
Post Processing
Use this option to reprocess the NCOM files from Hunter or Target to extract the Range or Lane measurements
RTCommunicationPC.dll Version 15.08.26.0 14bb PostProcessing.dll Version 15.09.19.0 14bg
Please click here to start the Line Survey Wizard
151001.14bd

Lane Survey. The Lane Survey Wizard is used to survey the lane markings on the road. Several lines are used to generate a map. Each line file has an RTRL extension and consist of GPS information such as latitude, longitude, altitude, number of satellites and measurement accuracy. The main window of the Lane Survey Wizard will show

the position and orientation of added points. It also updates the current position and orientation in real-time using the measurements from the RT.

Map Creation. The Map Creation Wizard creates maps using the line files that have been recorded using the Lane Survey Wizard. This wizard gives the flexibility of adding new points to a line, deleting points from a line or changing the position of the point on the map using the mouse. Lines added to the map can be deleted from the map and the order of points in the line can be reversed so that surveys conducted in reverse make sense. A map file may contain up to eight lines. The file extension for the map files is RTRM. Using the Map Creation Wizard you can add the start line to the map.

Real-Time Display. Once the map files are created the Real-Time Display can be used to download the map files and feature point files to the RT-Range, configure other RT-Range settings and display the RT-Range measurements in real-time. RT-Range measurements can be stored to files using the Real-Time Display.

Post-Processing Wizard. The Post-Processing Wizard can be used to reprocess the NCOM files from the hunter vehicle and target vehicles for range measurements; use a map file for lane position measurements and/or use fixed point file for fixed point range measurements. The lane and range measurements are saved in a CSV file format. The Post-Processing Wizard can also be used to convert the binary files stored by the Real-Time Display into CSV format.

PC configuration

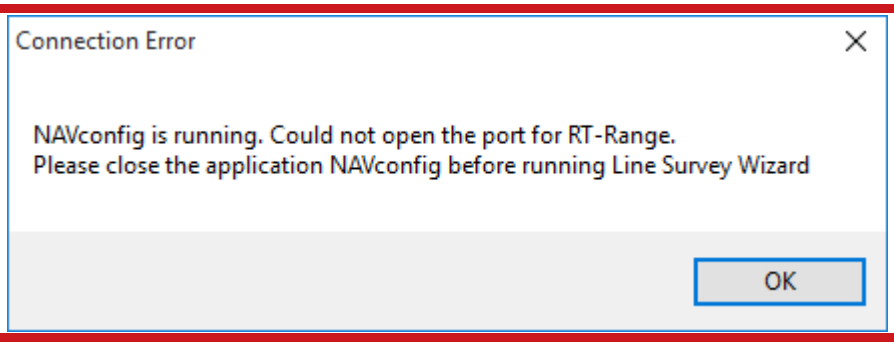
The RT-Range software communicates with the RT-Range hardware and the RTs using Ethernet. For this communication to work, the Ethernet of the PC has to be configured correctly.

The PC should have an IP address in the range 195.0.0.2 to 195.0.0.9, or any other Ethernet address on this network that is not used. The subnet mask should be 255.255.255.0.

The RT-Range software needs to open Ethernet port 3000 to communicate with the RT in the hunter (or target) vehicle. This port can only be opened by one application at a time; if any other application is running and has the port open then the error message in Figure 16 will be shown. For the RT-Range software to operate correctly the other application will have to be closed.

OxTS has a utility that can be installed on a computer so that the data from each RT can be shared. Contact OxTS support in order to use this utility.

Figure 16. Connection error message

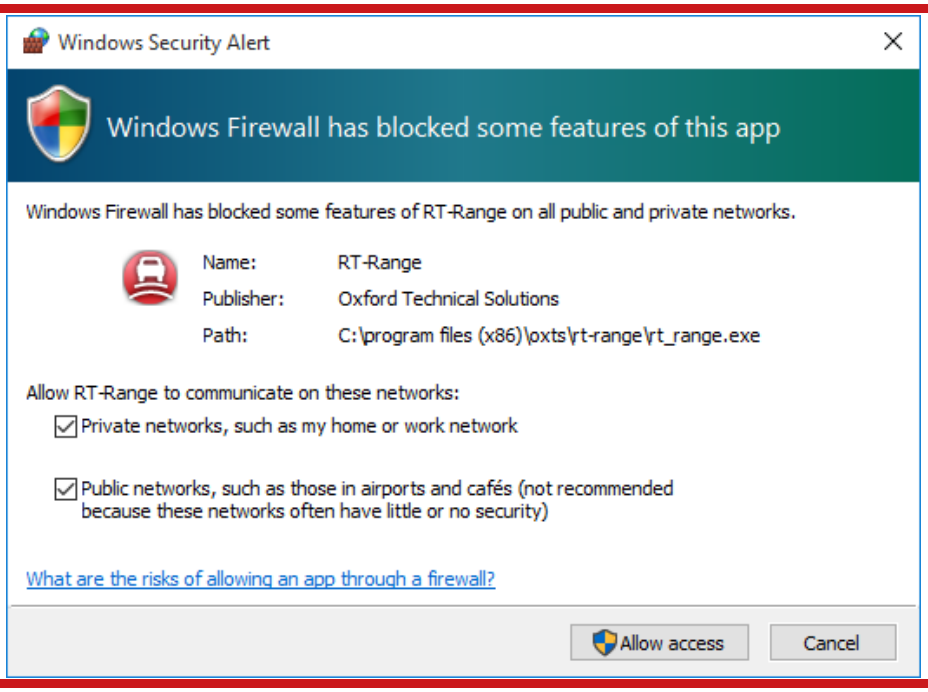

Connection Error
NAVconfig is running. Could not open the port for RT-Range.
Please close the application NAVconfig before running Line Survey Wizard
OK

Anti-virus software

Many anti-virus or firewall programs will block the ports and they give no indication that they are blocking the ports. If you are not receiving data from the RT or RT-Range systems then the most likely problem is any anti-virus software. In large companies the anti-virus software is hidden and the users do not even know it is there. It is very hard to debug such systems.

The first time some OxTS applications are run, a firewall warning message similar to that shown in Figure 17 may be triggered. This is because the program is attempting to listen for, and communicate with, OxTS devices on the network. The firewall must be configured to allow each program to talk on the network, or programs will not work as intended.

Figure 17. Windows Firewall warning message


Windows Security Alert
Windows Firewall has blocked some features of this app
Windows Firewall has blocked some features of RT-Range on all public and private networks.
Name: RT-Range
Publisher: Oxford Technical Solutions
Path: C:\program files (x86)\oxts\rt-range\rt_range.exe
Allow RT-Range to communicate on these networks:
Private networks, such as my home or work network
Public networks, such as those in airports and cafés (not recommended because these networks often have little or no security)
What are the risks of allowing an app through a firewall?
Allow access
Cancel

Ensure both Private and Public networks are selected to ensure the software can continue functioning when moving from one type to another.

Lane Survey Wizard

The Lane Survey Wizard is used with an RT that is mounted on a trolley, such as the Survey Trolley option. It is also possible to survey the lines with the RT in a car but it is very hard, if not impossible, to drive the car along the lane markings accurate to 2 cm or better. The quality of the driving, or how the trolley is pushed, will directly affect the performance of the lane position measurements. The Line Survey software is not designed to add more than one point per second, so car based surveys will need to be driven slowly or have a large gap between the line points.

Before attempting to use the Lane Survey Wizard module the user must set up the RT on the Survey Trolley. The RT needs to be initialised and operating correctly. Waiting for the warm-up period is not strictly required but the RT will be able to smooth GPS jumps if it is allowed to warm-up correctly and if it is given some motion during the warm-up period. More information is given in the Survey Trolley section.

Overview

The Lane Survey Wizard has four parts to its screen, the menus, the map, the RT measurement viewer and the spreadsheet viewer.

On the left-hand side are the menus and buttons that control the software. In the middle is a map that displays the current position and the position of points that have been

added to the line. In the top-right corner is the RT measurement viewer; this can be configured to show measurements from the RT such as velocity, heading, GPS position mode, number of satellites and other measurements useful when surveying. In the bottom-right is the spreadsheet viewer, showing numerical values for the points that have been added to the line.

Figure 18. Main screen of the Lane Survey Wizard

Selecting a line filename

Before running the Lane Survey Wizard, the file that will be used to record the line can be selected on the initial page of the RT-Range software, see Figure 15.

We suggest you put all the line files from one survey in their own directory and name the files Line1, Line2, Line3, etc. By putting a number at the end of the filename, the Lane Survey Wizard will automatically increment the number when you come to survey the next line.

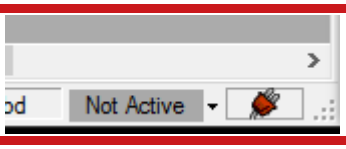
Connecting to the RT

The Lane Survey Wizard will accept data from any RT system on the network. The Lane Survey Wizard will work with multiple RTs on the network as long as the user applies the filter by selecting the relevant RT in the software. This is done using the NAVconnect window.

The NAVconnect window allows you to connect the relevant RT to the real-time display. It also has the ability to pass personalised Association tag and Tag id data onto the real-time display item for personalised reference against each device. The NAVconnect window is described in the Connection configuration using the NAVconnect window and Associations and tags section of this manual.

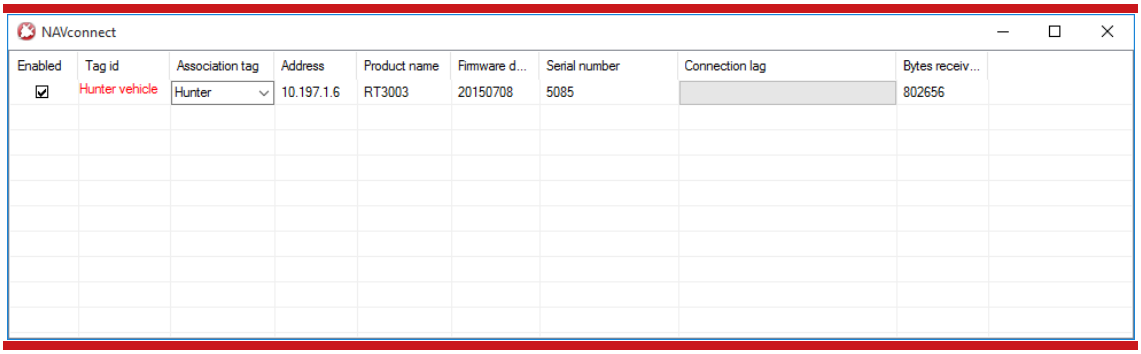
If you are using the hunter vehicle for a quick survey, then you may have more than one RT on the network at a time. To choose which RT is used for the line survey, click on the connection icon in bottom right corner as shown in Figure 19, this will open the NAVconnect window.

Figure 19. Connection icon in the RT-Range Line Survey status bar



In the NAVconnect window, Enable the RT that you want to use by identifying the device against the IP address then click *Enabled* as shown in Figure 20

Figure 20. IP addresses RT-Range NAVconnect window



The Tag id and Association tag can be renamed to pass through a personalised name to the display.

View options menu

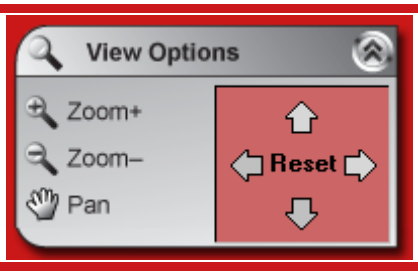
This menu allows you to zoom in or out and pan the map as shown in Figure 21.

Zoom+. Click on *Zoom+* to zoom in to the map; the maximum zoom level is a 1 metre grid square.

Zoom-. Click on *Zoom–* to zoom out of the map. The minimum zoom is a 1000 metre grid square.

Pan. The pan options allow the user to pan the map to left, right, up or down. If the user clicks on *Reset* in the pan option then it redraws the map centred on the current location given by the RT. The keyboard arrow keys can also be used to pan the map.

Figure 21. View options of the Lane Survey Wizard



Add point option menu

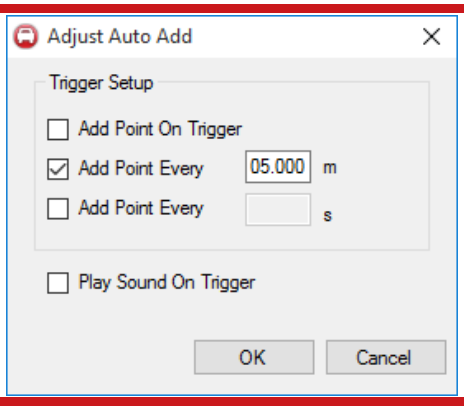
This menu controls how the points are added to the line file. The Add Point menu is shown in Figure 22.

Figure 22. Add Point menu of the Lane Survey Wizard

Add Points Here. The *Add Points Here* menu allows you to add a point to the map at the current point. This can be used as a manual method of adding points; it can be used to add a point when the auto add feature is off or it can be used to add in special points in between the points that are automatically added.

Adjust Auto Add. The *Adjust Auto Add* menu allows you to add points without interacting with the laptop. This can be easier to use on a trolley in bright sunlight than the laptop mouse. Figure 23 shows the options for the Auto Add Trigger.

Figure 23. Adjust trigger options of the Lane Survey Wizard



Add Point On Trigger. When this option is selected the Lane Survey Wizard will add a point when a trigger is sensed on the RT's Event Input.

Add Point Every (distance). When this option is selected the Lane Survey Wizard will add a point after the specified distance is travelled by the RT. This is the most common option.

Add Point Every (time). When this option is selected the Lane Survey Wizard will add a point periodically, such as once per second.

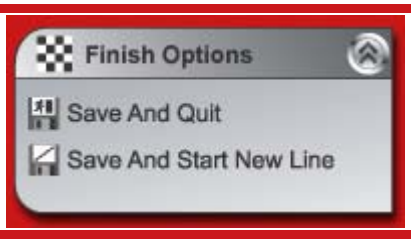
Play Sound On Trigger. When this option is selected the Lane Survey Wizard will play a sound to indicate that a new point has been added. This is useful since it is often hard to look at the computer while concentrating on the path of the trolley.

A dropdown list is provided so that the Auto Add Trigger can be turned on or off quickly. When the option is *Off* then the Auto Add Trigger is disabled and points are not added automatically.

Finish option menu

The Finish Option menu options allows the user to save the line file and quit the Lane Survey Wizard or save the line file and start a new line file. The Finish Options are shown in Figure 24.

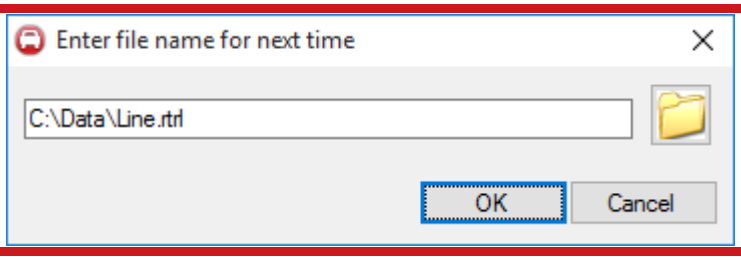
Figure 24. Finish Options of the Lane Survey Wizard



Save And Quit. This option saves the current line file and returns to the initial screen of the RT-Range Software.

Save And Start New Line. This option will save the current line file and start a new line file. The line filename automatically increments; for example, if the current filename was “Line1.rtrl” then it will set the new filename “Line2.rtrl”. If the current filename does not consist of an incremental number then the software will prompt for the name for the next file, as shown in Figure 25.

Figure 25. Next Filename dialog of Lane Survey Wizard



Display data menu

This menu allows the user to change the items displayed in the RT measurement viewer. Pages can be saved and loaded or items can be added to the display.

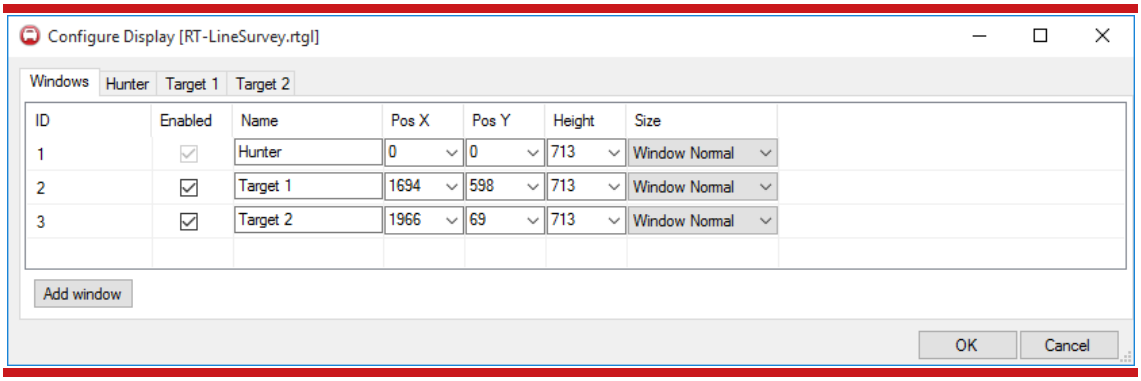
Figure 26. Display Data options of the Lane Survey Wizard

Open Display Page. This option can be used to load a page that has been previously saved using the *Save Display Page* or *Save Display Page As* options. The files extension for the Display Page files is RTGL.

New Display Page. This option clears the screen of all the display items.

Configure Display. This option is used to add Display Items to the RT measurement viewer. The user can also choose to have multiple windows each showing different measurements. After clicking on "Configure Display", the user can select the required measurements and the amount of windows. By clicking "Add window", the user can add more windows and name them appropriately as shown in Figure 27.

Figure 27. Add Windows in the Configure Display window



The user can specify the measurements displayed in each window as shown in Figure 28, and described in Table 12.

Figure 28. Add Measurements in the Configure Display window

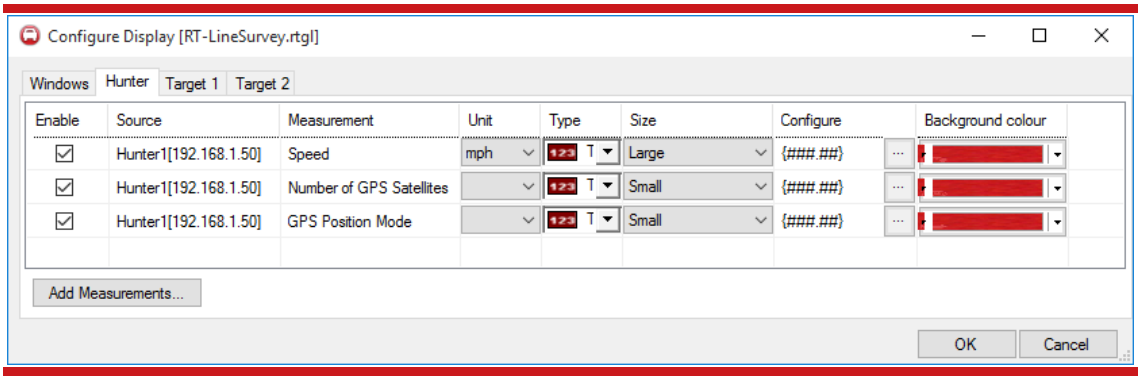


Table 12. Configure Display window descriptions

Column	Description
Enable	Enabling this check box allows you to display/hide this measurement on the display window.
Source	Decoded data provided by the RT-Range or INS system (physical source such as hunter car etc.)
Measurement	Description of the measurement set for the display control
Unit	Unit of measurement
Type	Display type (Text, Graph or Alert bar)
Size	The display control size can be Small, Medium and Large
Configure	Allows to set the properties of the display control format, limits, unit etc.
Background colour	Display control's background colour associate to the physical source colour i.e. red background colour is associated to a red car.

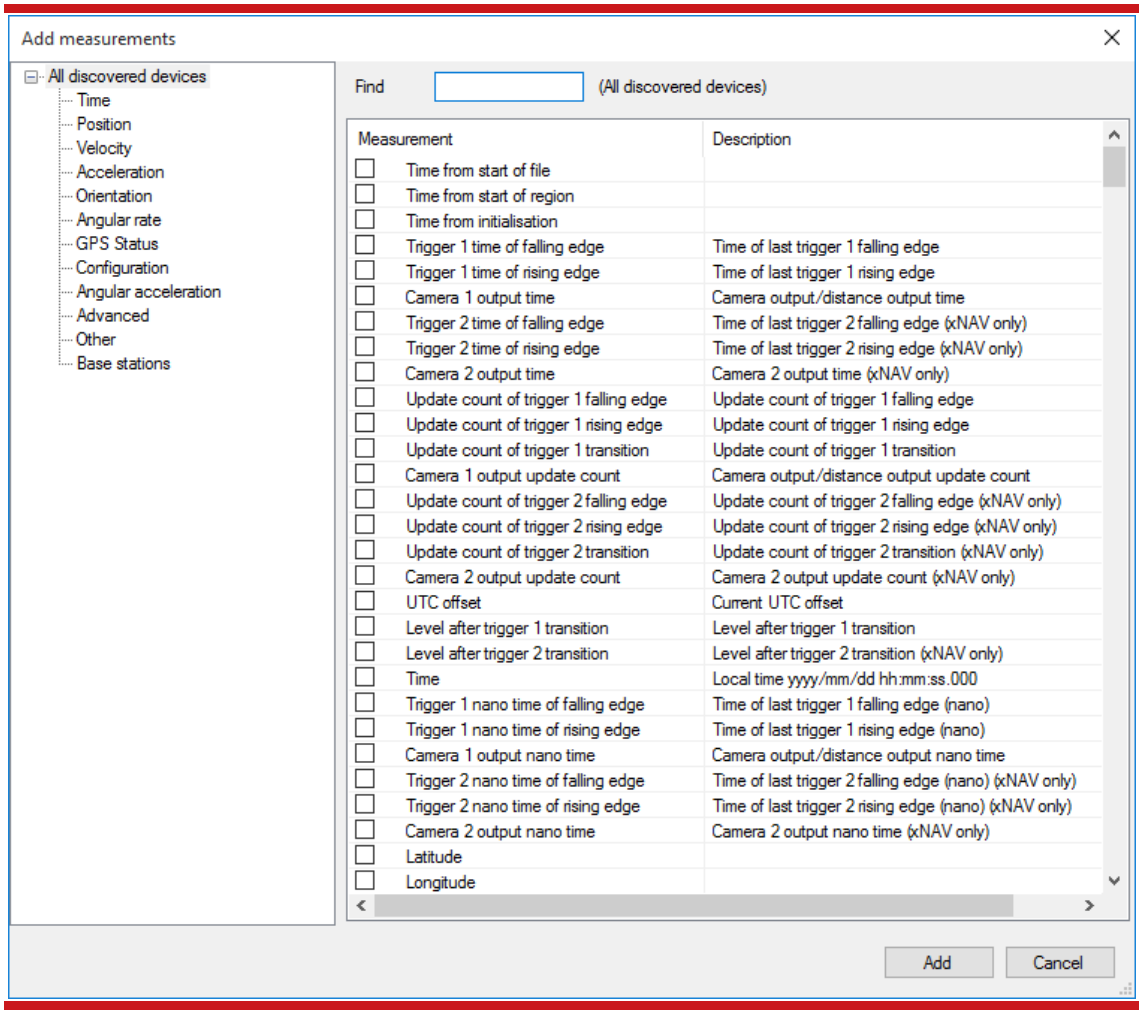
There are three types of items that can be inserted: *Graphs*, *Text* or *Alert Bars*. The properties of these items can be set in this window. I.e. Measurement unit, unit size, text format (Configure) and background colour. The background colour is useful for quickly identifying different types of measurements in the display.

Clicking the "Add Measurements…" button will open a new window where it is possible to select the required measurements for each individual window as shown in Figure 29.

The "Add Measurements" dialog box makes it possible to find and add measurements to the Real-time Display from any of the available measurements. All the measurement types available from each device are grouped by that device and its associated measurement categories. These are then displayed on the left side in a hierarchical tree structure. The individual measurements available to pick by those categories are

displayed on the right. When a category is selected using the mouse or arrow key, all the measurements in the tree structure under that category are displayed.

Figure 29. Add Measurements Window


Add measurements
All discovered devices
Time
Position
Velocity
Acceleration
Orientation
Angular rate
GPS Status
Configuration
Angular acceleration
Advanced
Other
Base stations
Find
(All discovered devices)
Measurement
Description
Time from start of file
Time from start of region
Time from initialisation
Trigger 1 time of falling edge
Time of last trigger 1 falling edge
Trigger 1 time of rising edge
Time of last trigger 1 rising edge
Camera 1 output time
Camera output/distance output time
Trigger 2 time of falling edge
Time of last trigger 2 falling edge (xNAV only)
Trigger 2 time of rising edge
Time of last trigger 2 rising edge (xNAV only)
Camera 2 output time
Camera 2 output time (xNAV only)
Update count of trigger 1 falling edge
Update count of trigger 1 falling edge
Update count of trigger 1 rising edge
Update count of trigger 1 rising edge
Update count of trigger 1 transition
Update count of trigger 1 transition
Camera 1 output update count
Camera output/distance output update count
Update count of trigger 2 falling edge
Update count of trigger 2 falling edge (xNAV only)
Update count of trigger 2 rising edge
Update count of trigger 2 rising edge (xNAV only)
Update count of trigger 2 transition
Update count of trigger 2 transition (xNAV only)
Camera 2 output update count
Camera 2 output update count (xNAV only)
UTC offset
Current UTC offset
Level after trigger 1 transition
Level after trigger 1 transition
Level after trigger 2 transition
Level after trigger 2 transition (xNAV only)
Time
Local time yyyy/mm/dd hh:mm:ss.000
Trigger 1 nano time of falling edge
Time of last trigger 1 falling edge (nano)
Trigger 1 nano time of rising edge
Time of last trigger 1 rising edge (nano)
Camera 1 output nano time
Camera output/distance output nano time
Trigger 2 nano time of falling edge
Time of last trigger 2 falling edge (nano) (xNAV only)
Trigger 2 nano time of rising edge
Time of last trigger 2 rising edge (nano) (xNAV only)
Camera 2 output nano time
Camera 2 output nano time (xNAV only)
Latitude
Longitude
Add
Cancel

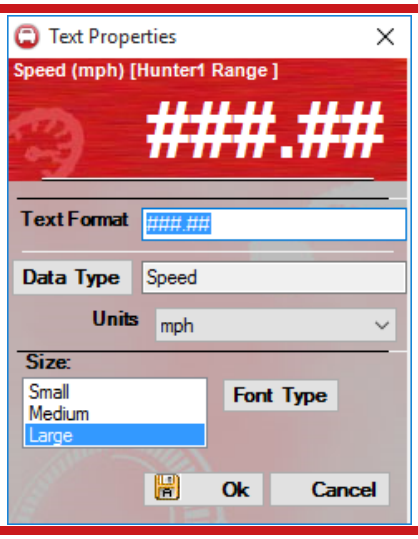
To select each measurement, click the check box to mark it ready for adding to the Configure Display window. To find a measurement, enter your search phrase in the "Find" text box at the top of the dialog box window. As you enter the search phrase, the Add measurements tool will automatically search through all the available measurements by measurement and description. The search can be restricted to a smaller subset by selecting a category of measurements rather than all the measurements in the file or files. Click "Add" to complete and add your selections. You can add further measurements at any time by repeating this process.

The first group of categories in the top left-hand side window is called "All discovered devices". All available measurements are here and it is possible by selecting just one measurement, to add that measurement to the Configure Display window for each of

the devices. For example, if the measurement "Time" is picked from the "All discovered devices" group, one instance of the Time measurement will (where time is a valid measurement for that device) be added to the Configure Display window for each device found.

Once a Display Item has been added to the Real-time Display window, the user can change its properties by right-clicking on the item. This opens the Text Properties window shown in Figure 30. Please note that the background colour cannot be changed from within the Display item properties box.

Figure 30. Display Item properties



Display Items can be moved up and down by dragging and dropping them into the required position. Display Items can also be moved between different windows in the same way.

Save Display Page. This option saves the Display Page to the current file.

Save Display Page As. This option saves the Display Page to a new file.

Spreadsheet Viewer

This viewer is the spreadsheet at the bottom right of the window. It shows the points that have been added to the map in numerical format. Measurements of latitude, longitude, altitude, heading, north accuracy, east accuracy, down accuracy, number of GPS satellites and GPS position mode are shown. The user does not have the option to change the measurements properties of the spreadsheet. These are the measurements that are saved in the line file and used to generate the map.

Map Creation Wizard

The Map Creation Wizard takes the line files made by the Lane Survey Wizard and assembles them into a map.

Selecting a map filename

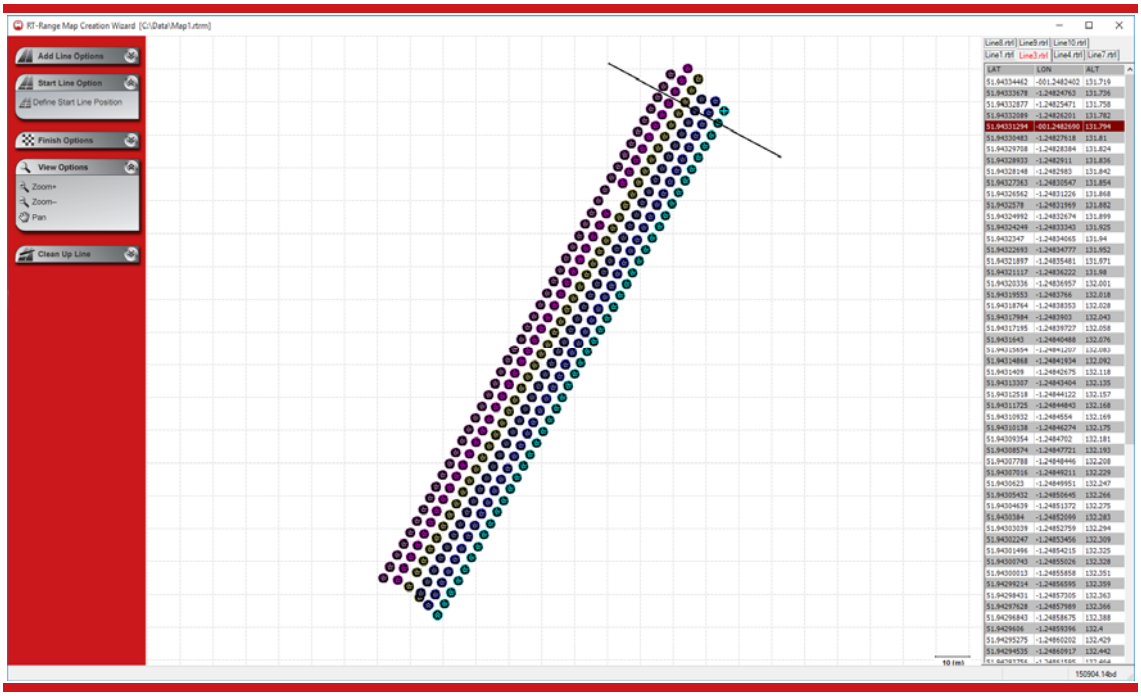
Before running the Map Creation Wizard, the filename that will be used to save the map can be selected from the initial page of the RT-Range software, see Figure 15. We recommend you create the map file in the same directory as the line survey files as this will make it quicker to select and add each line survey file. The filename extension for a map file is RTRM.

Overview

The layout of the Map Creation Wizard is very similar to the Lane Creation Wizard with the exception that the RT measurements are not present.

On the left-hand side are the menus and buttons that control the software. In the middle is a map that displays all the points on the lines that have been added. On the right is the spreadsheet viewer, showing numerical values for the points in the lines that have been added. Each line is shown in a tab. The tab contains a spreadsheet view of the line's measurements such as latitude, longitude, altitude and heading.

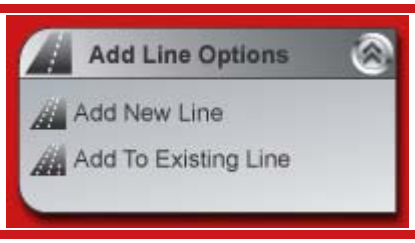
Figure 31. Main screen of the Map Creation Wizard



Add Line Options

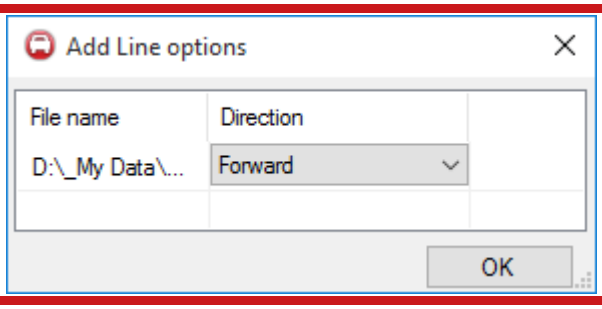
The Add Line Options menu allows the user to add additional line files to the map. Figure 32 shows the Add Line Options of the Map Creation Wizard.

Figure 32. Add Line Options of the Map Creation Wizard



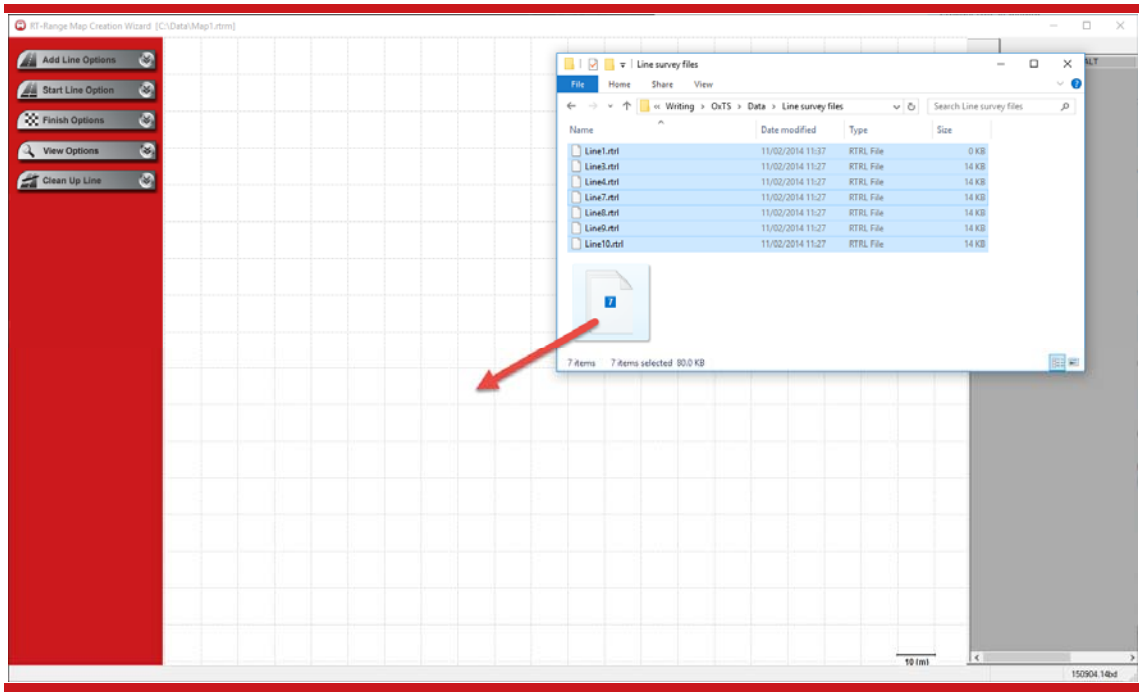
Add New Line. This option is used to add a new line to the map. From the Open File dialog box select a new line file with an RTRL extension. After the line is selected the *Add Line Options* dialog box will appear. The line can be added in the forward (or normal) direction or in the reverse direction (i.e. the line was surveyed starting at the end and finishing at the start). Figure 33 shows the *Add Line Option* dialog box.

Figure 33. Add Line Options of the Map Creation Wizard



Users can also select multiple line files and add them to the map by selecting the line files from Windows Explorer and drag and drop them onto the map as shown in Figure 34.

Figure 34. Add Multiple Line Files to the Map Creation Wizard



Add to Existing Line. This option is used to add one line to another line on the map. The new line will be added to the end of the existing line; there is no way to add the new line to the start of the existing line, so the lines must be added in the correct order. New lines can be added in forward or reverse directions.

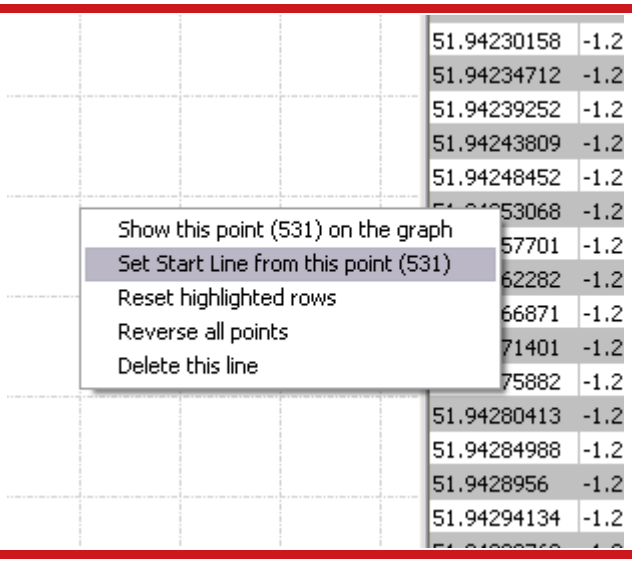
Start Line Option

The RT-Range lane position measurements start when the vehicle crosses the start line. This reduces the real-time search requirements of the RT-Range and also enables the RT-Range to have maps with crossing lines.

It is essential to set the position of the start line before the start line options can be set. The start line is based on one of the points at or near the start of one of the lines (normally the central line).

In order to add a start line, first select a point on the map by double-clicking the point. In the spreadsheet viewer the point will be highlighted. Right-click the highlighted point in the spreadsheet viewer and select *Set Start Line from this point*, as shown in Figure 35. Now the start line is set and will be drawn on the map display.

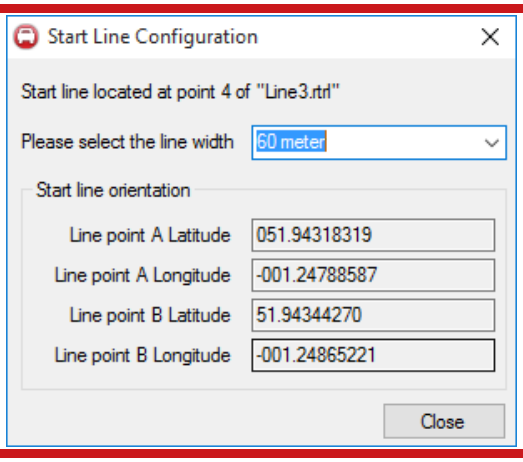
Figure 35. Setting the Start Line in the Map Creation Wizard



Note that the start line is directional and will only trigger in the direction of the map.

Define Start Line Position. Once the start line has been set, the *Define Start Line position* option allows the user to change the start line width.

Figure 36. Setting the Start Line in the Map Creation Wizard



Finish Options

This menu has options to save the map file. Note that map files cannot be saved until a start line has been set.

Save. This option saves the map file to the last file that was saved. This will be the file specified in the initial page of the RT-Range software or the last file that was specified using the *Save As* option.

Save and Quit. This option performs a *Save* (i.e. to the last file) and then returns to the initial page of the RT-Range software.

Save As. This option saves the map file to a new name. Enter the new name in the Save As dialog box that appears.

View Options

This menu allows you to zoom in or out and pan the map as shown in Figure 21, above. It behaves in the same way as the *View Options* in the Lane Survey Wizard.

Zoom+. Click on the *Zoom+* to zoom in to the map; the maximum zoom level is a 1 metre grid square.

Zoom-. Click on the *Zoom–* to zoom out of the map. The minimum zoom is a 1000 metre grid square.

Pan. The pan options allow the user to pan the map to left, right, up or down. If the user clicks on the *Reset* of the pan option then it redraws the map so that the whole survey fits within the window. The keyboard arrow keys can also be used to pan the map.

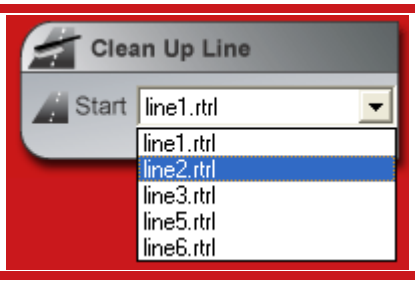
Clean Up Line

When surveying using the Lane Survey Wizard you may add some points incorrectly, for example too close together. The Clean Up Line Tool identifies Lines that have undesirable points (from a calculation perspective) and steps the user through the process of tidying up the points.

There is some discussion in the Calculation Discussion section on what makes a point undesirable and on the best way to survey lane markings.

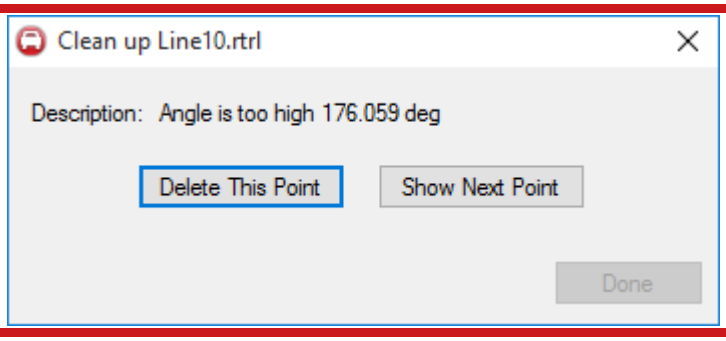
Figure 37 shows the Clean Up Line menu.

Figure 37. Clean Up Line menu in the Map Creation Wizard



The Clean Up Line Tool automatically identifies the lines that need some attention and only shows these in the dropdown list. To start the process of cleaning up a line, select the line from the dropdown list and click on *Start*. This will display the Clean Up Line dialog box, as shown in Figure 38.

Figure 38. Clean Up Line dialog box in the Map Creation Wizard



The Clean Up Line Tool will zoom the map to a 1 m grid spacing automatically. Then it will highlight the point on the line that has violated the rules. The user has the option of deleting the point or moving to the next point.

The Clean Up Tool will highlight the *first* point that violates the rules. This violation will be based on points that are both behind and ahead of the current point. It is not necessarily the first point that is wrong. Figure 39 shows a point that has been highlighted by the Clean Up Line tool. This point violates the rules because the angle to the next point is too large, i.e. the line is not straight enough. It is clear to the user that it is the next point that is in error and the current point should not be deleted. By clicking *Show Next Point* the user can skip this point and move on to the next point.

Figure 39. Clean Up Line example point

Map View

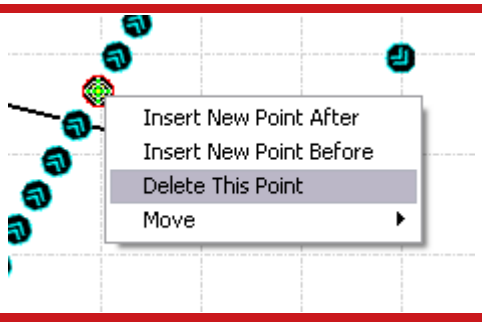
The Map View shows all of the points in all of the lines. Within each point is an arrow showing the direction to the next point.

Points can be selected by double-clicking. Points that are selected appear highlighted in the spreadsheet viewer.

Selected points can be moved by dragging the mouse. It is not clear that this is a useful feature since the survey needs to be performed very accurately and it is not easy to adjust things accurately using the mouse. The scale of the computer screen is too different to that of the road so that small motions on the mouse are large changes on the road. However, if we provided a greater zoom then you would not be able to see the surrounding points and the adjustment would not make sense.

Right-clicking on a selected point shows a menu, as shown in Figure 40.

Figure 40. Map Point Menu the Map Creation Wizard



Insert New Point After. The *Insert New Point After* function inserts a point half way between the current point and the next point, i.e. further along the line.

Insert New Point Before. The *Insert New Point Before* function inserts a point half way between the current point and the previous point, i.e. not as far along the line.

Delete This Point. The *Delete This Point* function deletes the selected point.

Move. The *Move* function allows the user to move the selected point. It will move the selected point by 1 pixel on the grid. The value of 1 pixel changes depending on the grid size. The scale factors are shown in Table 13.

Table 13. Scale factors for the move function

Grid size	'Move' option shifts point by…
1.0 m	0.02 m
2.5 m	0.05 m
5.0 m	0.10 m
10.0 m	0.20 m
25.0 m	0.50 m
50.0 m	1.00 m
100.0 m	2.00 m
250.0 m	5.00 m
500.0 m	10.00 m
1000.0 m	20.00 m

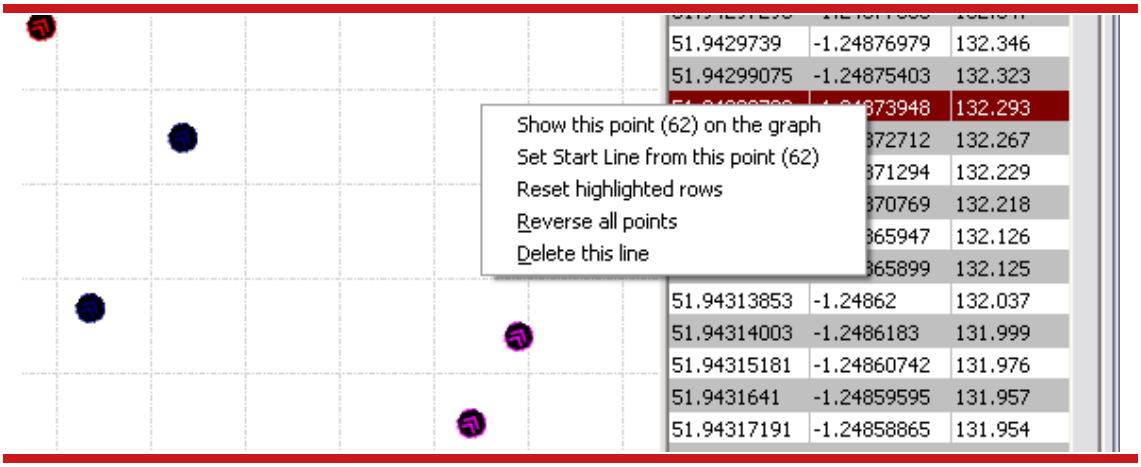
Spreadsheet Viewer

The spreadsheet viewer shows numerical values for all of the points in the correct order. Lines that are loaded in reverse will be shown with the last point of the line in the first row of the spreadsheet viewer.

Points that are highlighted on the Map View will be highlighted in the spreadsheet viewer.

By right-clicking on a row of the spreadsheet viewer, the spreadsheet pop-up menu will appear. This is shown in Figure 41.

Figure 41. Map Point Menu the Map Creation Wizard



Show this point (*i*) on the graph. This function centres the point corresponding to the spreadsheet row in the map window and highlights (selects) it.

Set Start Line from this point (*i*). This function is used to set the point for this spreadsheet row as the start line. Once set, the user can adjust the start line options using the menu on the left.

Reset highlighted rows. This function is used to cancel the selection.

Reverse all points. This function reverses all of the points in this line. To reverse the entire map each line must be individually reversed.

Delete this line. This function removes the line from the map.

Real-Time Display

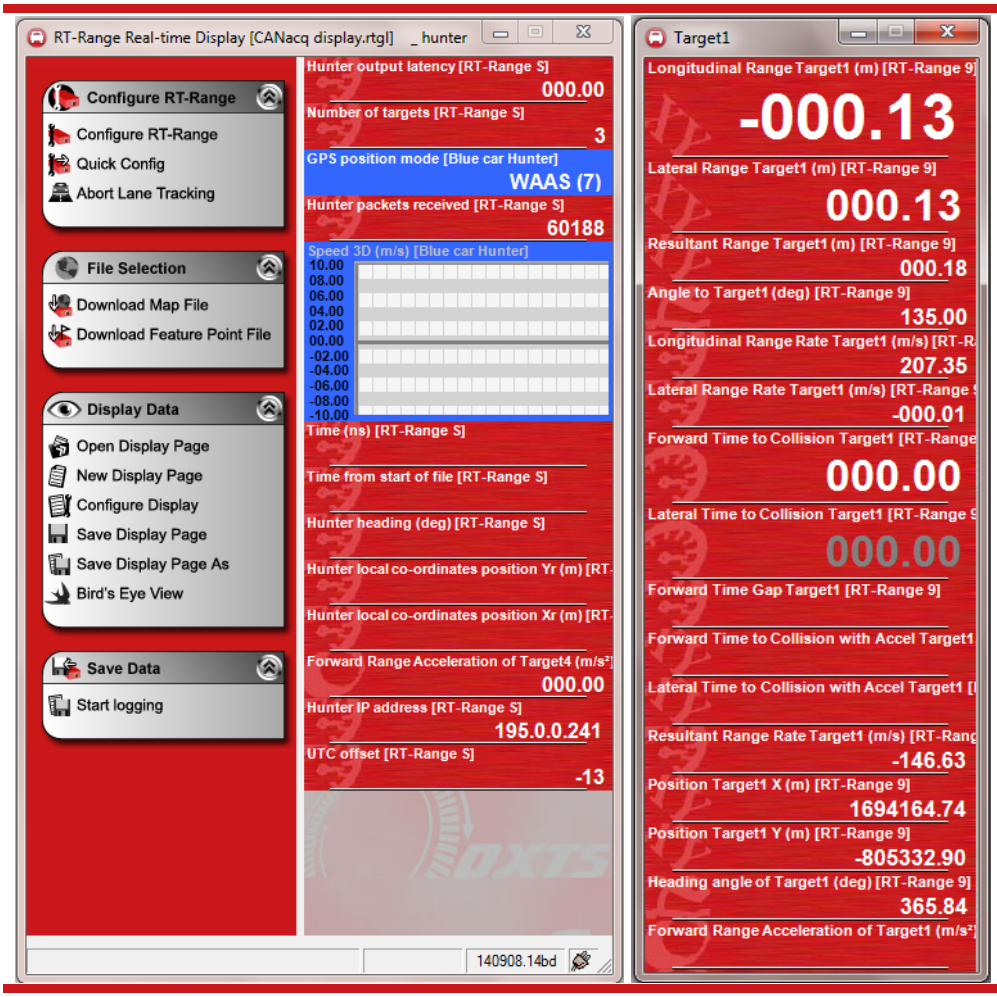
The Real-Time Display module is capable of displaying real-time data, with a high update-rate, from a variety of sources. These include the RT-Range system, any of the RTs on the network and any associated CAN data—where the CAN acquisition feature has been enabled for the RT in that vehicle.

It is also used to download map files or feature point files, set the fixed positions, set the ranging mode and configure the RT-Range hardware.

Overview

The Real-time Display window has two sections. On the left is the menu system and on the right are the measurements. Additional measurement windows can be opened and configured. The layout of the screen is shown in Figure 42.

Figure 42. Layout of the Real-Time Display window



Note: The Display Items on the right-hand side can be changed; this is just a selection of the available measurements that can be displayed and what they can look like.

Configure RT-Range menu

The Configure RT-Range menu is used to change the setup and operating mode of the RT-Range.

Configure RT-Range. This option is used to run the RT-Range Configuration Wizard. This wizard is used to set the more permanent parameters of the RT-Range and will probably only be used for a new installation in a vehicle. There are many parameters in the RT-Range Configuration Wizard and it is described in its own section later in this manual.

Quick Config. The Quick Config option is used to change some of the real-time settings of the RT-Range without rebooting. Options that can be changed using the Quick Config window include the lateral and longitudinal offset, range mode, fixed point locations and the local co-ordinates used for the RT-Range. More details on the Quick Config are given in the section below.

Abort Lane Tracking. The RT-Range will continue tracking the lane position until the car drives past the final point on Line 1. The lane position measurement can be aborted early by clicking on this button.

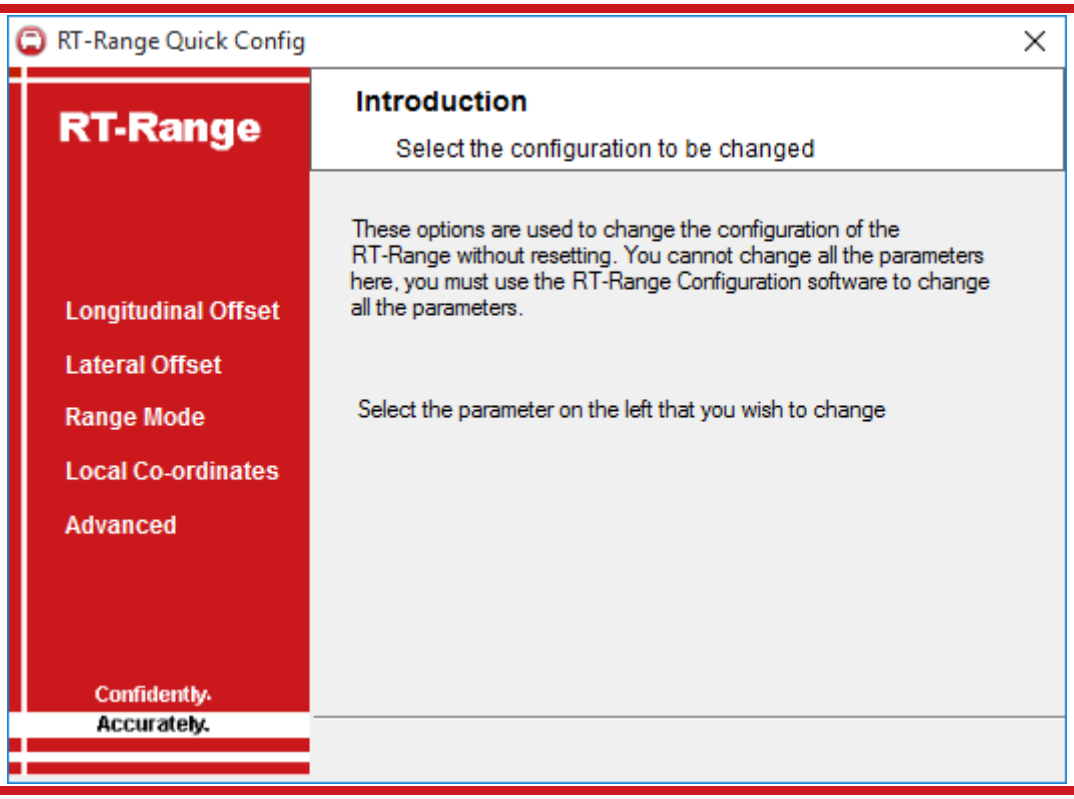
It is not normally necessary to abort the lane tracking since the lane tracking will start from the beginning as soon as the start line is crossed. However, if you need to have negative "Distance along Lane1" before your test then you may need to use this feature to cancel the current lane tracking before starting a new test.

RT-Range Quick Config

The RT-Range Quick Config window can be used to modify some of the behaviour of the RT-Range without needing to reboot. Figure 43 shows the introduction window of the RT-Range Quick Config window.

From the Quick Config window, one of the options on the left hand side needs to be selected. Each of these options is described below.

Figure 43. RT-Range Quick Config introduction window

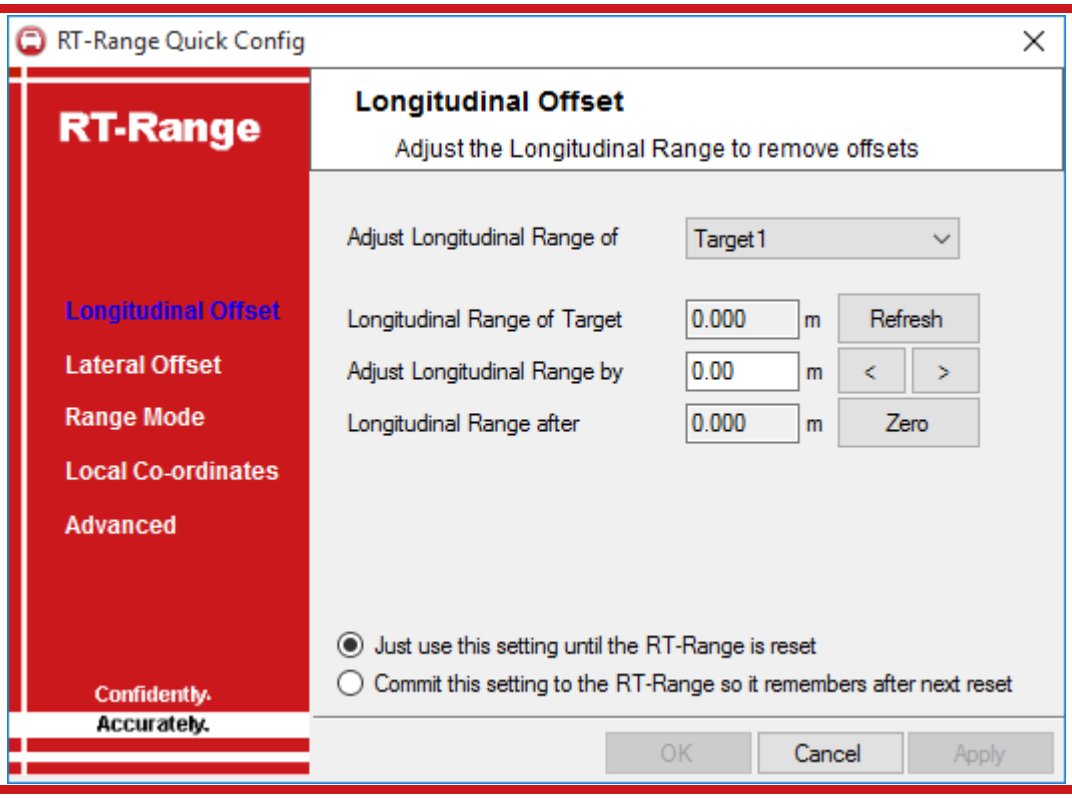

RT-Range Quick Config
RT-Range
Introduction
Select the configuration to be changed
These options are used to change the configuration of the RT-Range without resetting. You cannot change all the parameters here, you must use the RT-Range Configuration software to change all the parameters.
Select the parameter on the left that you wish to change
Longitudinal Offset
Lateral Offset
Range Mode
Local Co-ordinates
Advanced
Confidently.
Accurately.

Longitudinal Offset. The longitudinal range of the RT-Range can be adjusted or offset to account for small errors in the configuration. This is not a substitute for measuring as

accurately as possible; it is a quick technique for making small changes to the longitudinal range.

Clicking on "Longitudinal Offset" brings up the Quick Config window on the Longitudinal Offset page, as shown in Figure 44. There may be a short delay while the software reads the current settings from the RT-Range.

Figure 44. Longitudinal Offset in the Real-Time Display



The display shows the current longitudinal range to the selected target. This is only refreshed when the "Refresh" button is pressed. To adjust the longitudinal range enter the adjustment in the "Adjust Longitudinal Range by" edit box or use the "<" and ">" buttons to increment or decrement the value. The "Longitudinal Range after" box shows longitudinal range after the offset has been applied. To zero the longitudinal range press the "Zero" button.

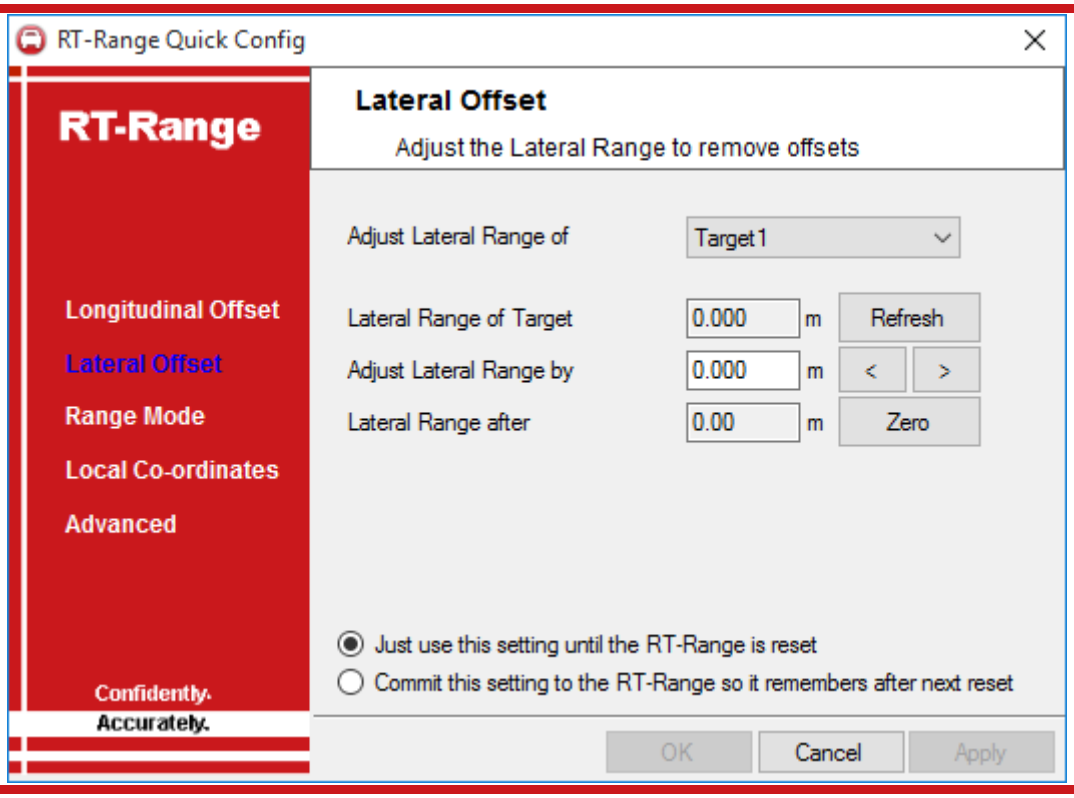
After the adjustment has been entered press "OK" or "Apply" in order to send the new longitudinal offset to the RT-Range.

The longitudinal offset can be saved permanently in the RT-Range or just used until the RT-Range is reset. To save it permanently select the "Commit this setting to the RT-Range so it remembers it after next reset" option.

Lateral Offset. The lateral range of the RT-Range can be adjusted or offset to account for small errors in the configuration. This is not a substitute for measuring as accurately as possible, it is a quick technique for making small changes to the lateral range.

Clicking on "Lateral Offset" brings up the Quick Config window on the Lateral Offset page, as shown in Figure 45. There may be a short delay while the software reads the current settings from the RT-Range.

Figure 45. Lateral Offset in the Real-Time Display



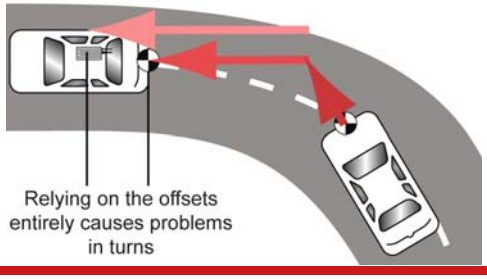
The display shows the current lateral range to the selected target. This is only refreshed when the "Refresh" button is pressed. To adjust the lateral range enter the adjustment in the "Adjust Lateral Range by" edit box or use the "<" and ">" buttons to increment or decrement the value. The "Lateral Range after" box shows lateral range after the offset has been applied. To zero the lateral range press the "Zero" button.

After the adjustment has been entered press "OK" or "Apply" in order to send the new lateral offset to the RT-Range.

The lateral offset can be saved permanently in the RT-Range or just used until the RT-Range is reset. To save it permanently select the "Commit this setting to the RT-Range so it remembers it after next reset" option.

The lateral range is particularly susceptible to unexpected errors when using the offsets to configure the vehicle. Consider the situation in Figure 46.

Figure 46. Using lateral offsets causes problems on turns



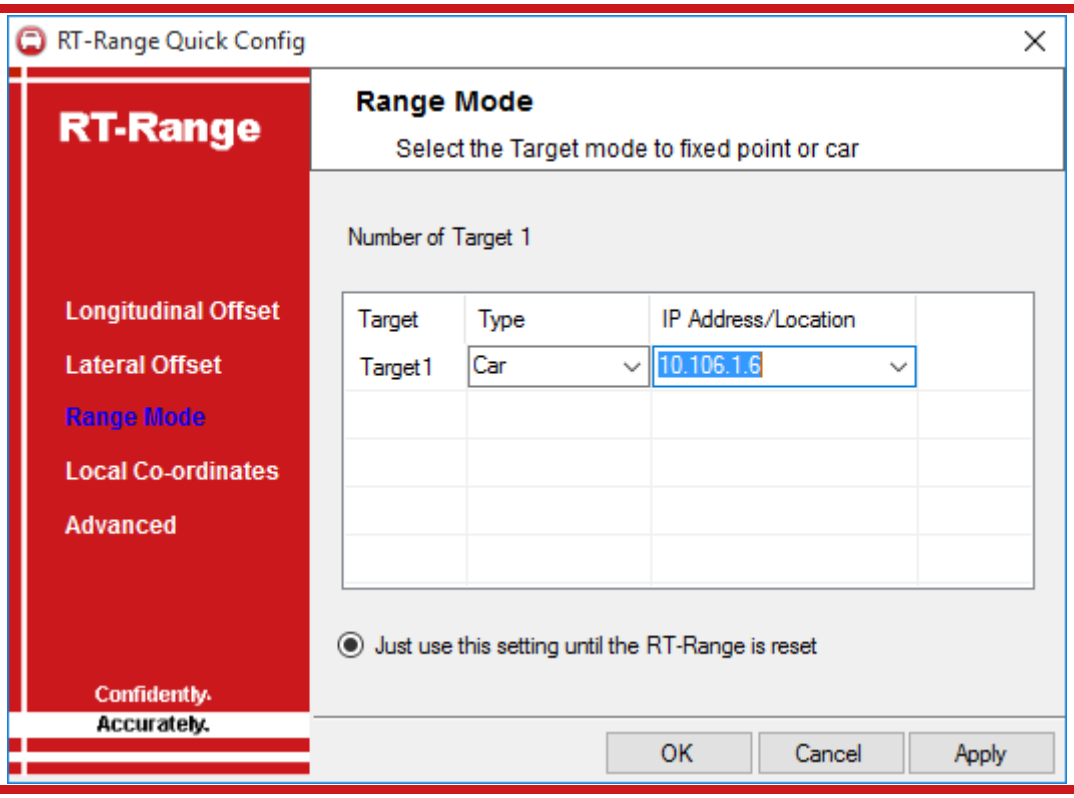
The RT-Range measures the range between the sensor position (on the hunter vehicle) and the bulls-eye position (on the target vehicle). This is shown using the darker red arrows.

Assume that the bulls-eye position on the target vehicle is not entered, so that the RT-Range measures to the RT's position and the longitudinal offset is used to correct this. If the vehicle now turns then the lateral range will track the pink arrow, which is clearly different to the result expected.

It is best to measure the sensor and bulls-eye position as accurately as possible and only rely on the longitudinal and lateral offsets for small adjustments.

Range Mode. There are three ranging modes in the RT-Range, car-to-car, fixed point and feature point. In fixed point mode the RT-Range measures the distance from the hunter vehicle to a fixed point rather than the distance to the target vehicle. A fixed point might be the corner of a parked car or a stationary target. In feature point mode a file containing thousands of feature points can be loaded into the RT-Range. These can represent objects such as road signs or traffic lights and the RT-Range can measure the distance from the hunter vehicle to these feature points. The range mode of the RT-Range is shown in Figure 47.

Figure 47. Target Configuration in the Real-Time Display

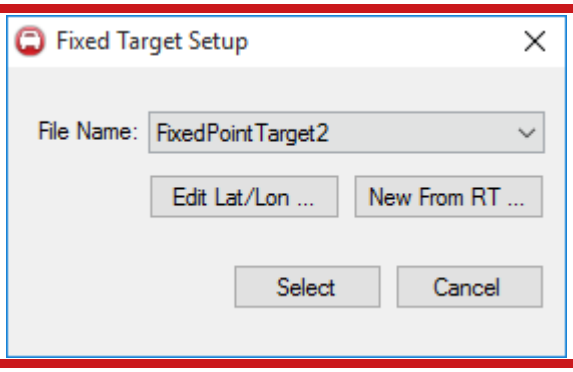


Targets 1 to 4 can be configured either to track target vehicles or to measure the distances to fixed points or feature points.

Note that the RT-Range Hunter does not know the filenames of the fixed points. If you receive the RT-Range data on a computer that does not have the fixed point files for example, then the software automatically creates a file and gives it a name. The RT-Range searches all the files in the fixed point file directory in order to find the fixed point that matches.

Fixed Point Mode. To change the fixed point that the RT-Range is tracking, click on the "…" button. This shows the Fixed Point Setup dialog box, as shown in Figure 48.

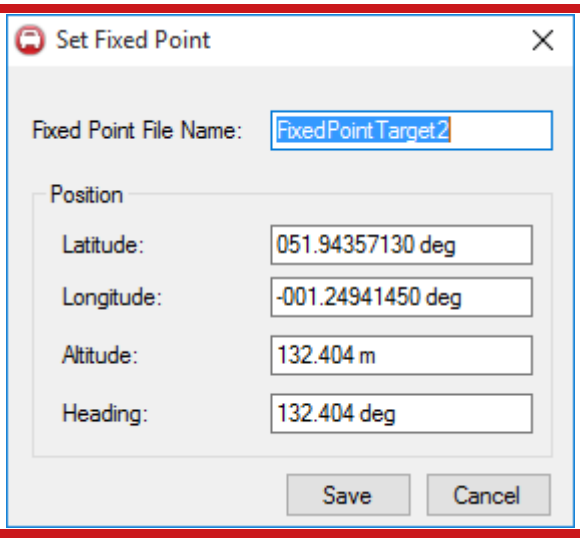
Figure 48. Fixed Target Setup window in the Real-Time Display



The fixed point is stored in a file. Select the file holding the latitude, longitude and altitude of the fixed point from the dropdown list. The fixed point files have extension RTFP.

New fixed points can be made by clicking on the *Edit Lat/Lon…*button or the *New From RT...* button. The *Edit Lat/Lon…*button shows the Set Fixed Point dialog box, as shown in Figure 49.

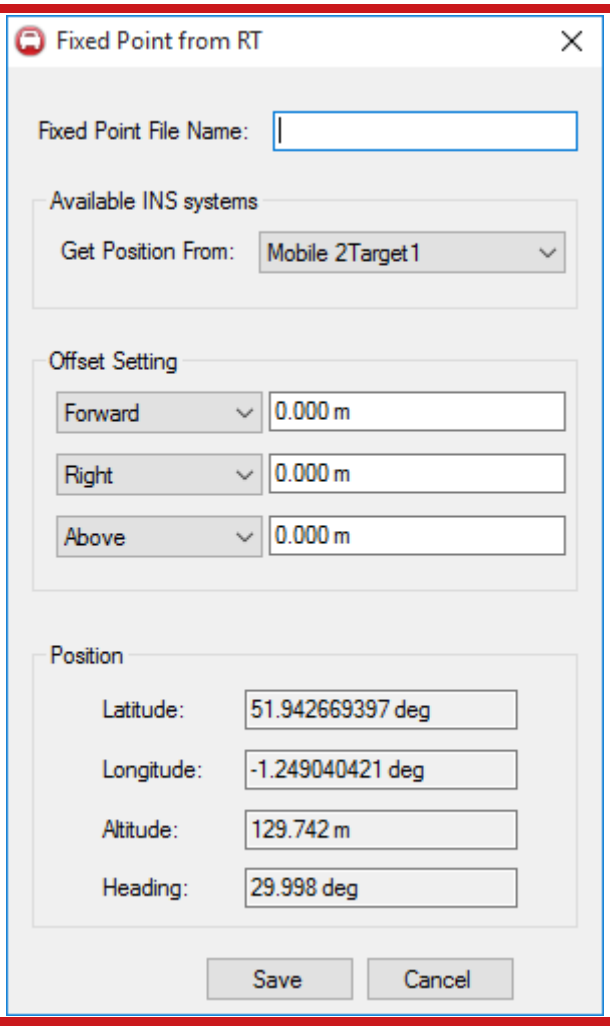
Figure 49. Set Fixed Point window in the Real-Time Display



The name of the fixed point is used to generate the filename and appears in the dropdown list of the Send Fixed Point dialog box. Enter the latitude, longitude and altitude of the fixed point. You will need to use a high precision (many decimal places) for the latitude and longitude values.

The *New from RT…* button gets the latitude and longitude values from any RT on the network.

Figure 50. Fixed Point from RT window in the Real-Time display



The name of the fixed point is used to generate the filename and appears in the dropdown list of the Send Fixed Point dialog box.

Select the desired RT from the dropdown dialog box. Because the RT may not be at the exact fixed point location, values can be entered to displace the fixed point location from the RT's position.

If there is no RT-Range on the network, the dialog box will not show the RT position. This is because the decoded RT data (latitude, longitude, altitude, and heading) are contained in the RCOM packets from the RT-Range. For this feature to work correctly, an RT-Range system must be connected to the network.

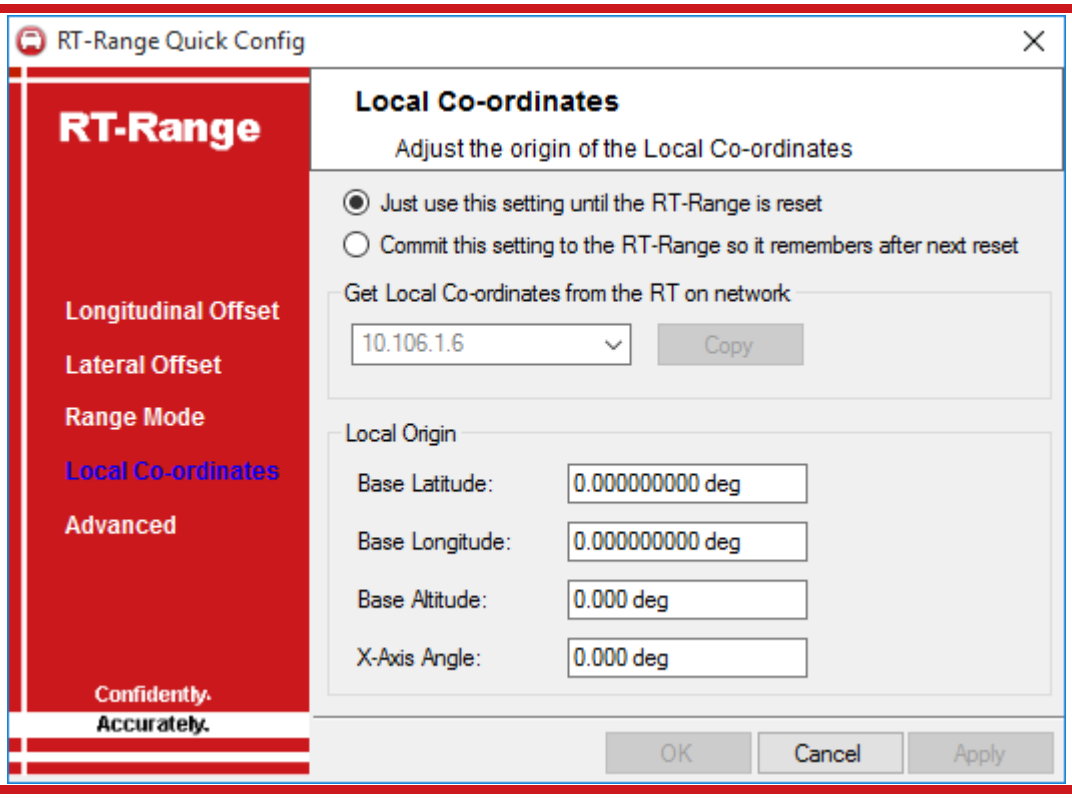
Mobile Target Mode. In this mode the RT-Range measures the position of a mobile target from the hunter vehicle. To track a mobile target (e.g. target vehicle, pedestrian

etc.) choose “Mobile Target” from the dropdown menu and select the IP address of the RT that is in the target vehicle.

Feature Point Mode. In this mode the RT-Range computes the range from the hunter vehicle to the appropriate predefined feature point. To use feature points choose “Feature Points” from the dropdown menu.

Local Co-ordinates. The RT-Range has its own set of local co-ordinates. These can be different to the local co-ordinates used by any of the RTs. Normally the local co-ordinates are configured as part of the RT-Range Configuration Wizard but they can be set and changed quickly using the Quick Config window. The RT-Range Quick Config Local Co-ordinates window is shown in Figure 51.

Figure 51. RT-Range Quick Config, Local Co-ordinates window



Local Co-ordinates can be configured temporarily to the RT-Range or they can be saved as part of the RT-Range configuration. To save them temporarily choose the “Just use this setting until the RT-Range is reset” option, in which case the original local co-ordinates will be restored when the RT-Range is reset. To change the configuration choose the “Commit this setting to the RT-Range so it remembers after next reset” option, in which case the new local co-ordinates will be saved and the old ones will be overwritten.

Using RT-Range Quick Config you can transfer the local co-ordinate settings of any RT on the network to the RT-Range. This synchronises the local co-ordinates used by that RT and the RT-Range.

In the dropdown list, select the RT whose local co-ordinates you want to copy and click *Copy*; this will copy them from the RT to the group box below. If you know the local co-ordinates already, you can type them in to the edit boxes directly. If the copy button is disabled then there is no data from the selected RT or the local co-ordinates are not enabled on that RT.

Press *Apply* or *OK* to send the local co-ordinates to the RT-Range.

Advanced. The Advanced window is used to send commands to the RT-Range. It is used for testing the RT-Range or when you have been specially directed to use it. You can reset the RT-Range through this window.

File Selection menu

The map file define the positions of the lanes for the lane position measurements. The RT-Range hardware will save and use the last map file that was downloaded, even after power-up.

Download Map File. This function can be used to download another map file to the RT-Range box. Map files have the extension RTRM. The RT-Range will start using the new map file as soon as the download cycle completes.

The RT-Range software remembers the last map file that was downloaded to the RT-Range and uses this file in the Bird's Eye View.

Download Feature Point Files. This function can be used to download a feature point file to the RT-Range unit. Feature point files have the extension FTL. The RT-Range will start using the new feature point file as soon as the download cycle completes.

The RT-Range software remembers the last feature point file that was downloaded to the RT-Range and uses this file in the Bird's Eye View.

Display Data menu

The Display Data menu configures the right-hand side of the Real-Time Display. The Display Data menu in the Real-Time Display is the same as the Display Data menu in the Lane Survey Wizard, except it also has the Bird's Eye View feature. Please refer to the section "Display data menu" earlier in the manual.

The Save Display functions also operate in the same way as the Lane Survey tool and can be saved to different templates depending on the tests being carried out. If at any time the windows are accidently closed and not saved as a template, the settings will be

automatically saved to a template file called “LastDisplay.rtgl”. Just open this template, and save to the new name.

Connection configuration using the NAVconnect window

The RT-Range software can connect, display and log data from one RT-Range system and multiple RT systems along with their associated CAN data (where the CAN acquisition feature is enabled in the RT).

The RT-Range, RT and CAN display configuration can be changed at any time by double-clicking the connection icon (shown as a “plug” in Figure 52) at the bottom right corner of the Real-Time display. This will bring up the NAVconnect window and show a list of the RT-Range and RT systems currently found on the network. This is shown in Figure 53.

Figure 52. Connection icon

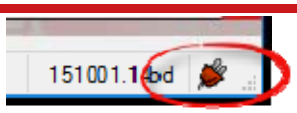
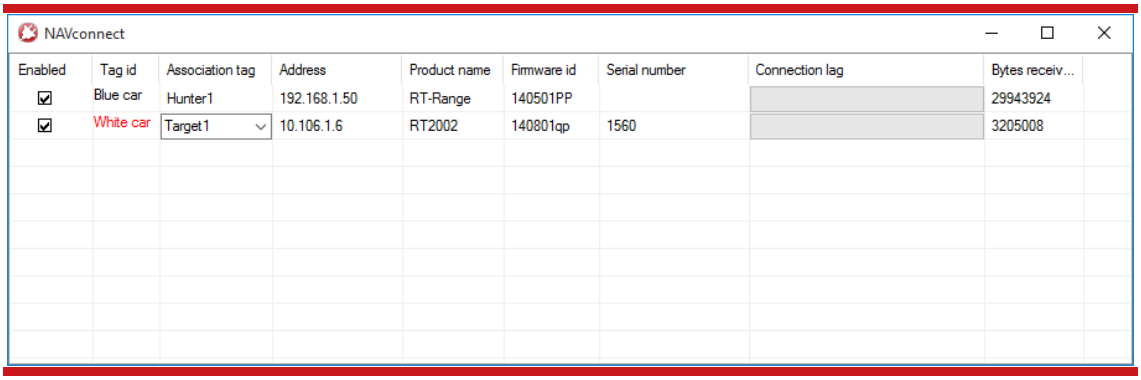


Figure 53. Select IP real time addresses; assign Tag id and Association tag



The Tag id and Association tag can be renamed to pass through a personalised name to the display.

To change which RT-Range or which RTs the software is connected to and displaying, they must first be enabled by checking the *Enabled* box alongside each device required in the list.

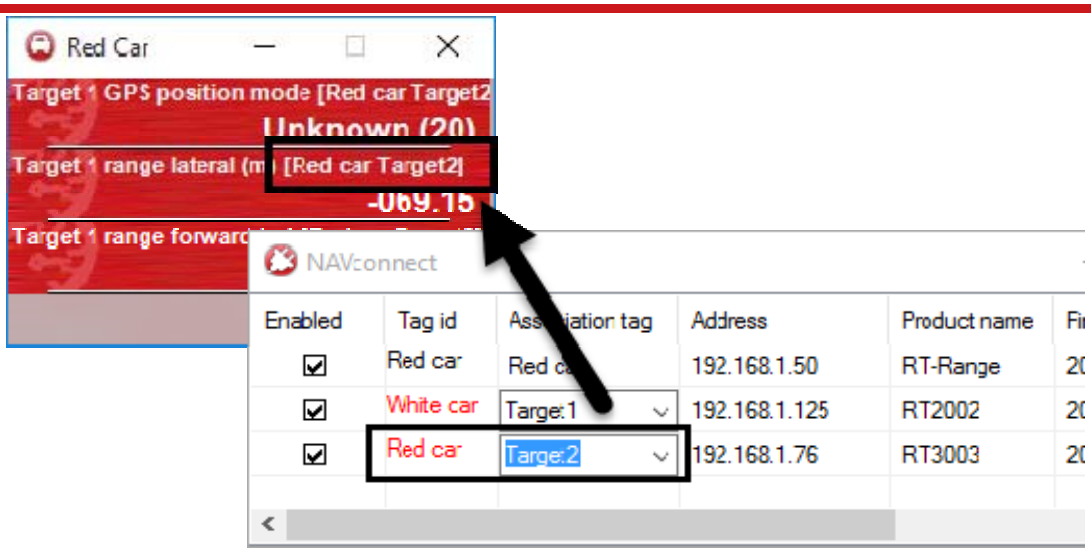
Associations and tags

The *Association tag* and *Tag id* is used to pass identifiable information about the vehicle against the vehicle type (hunter or target) through to the real-time display

windows. This information is extremely useful for validating the actual measurement back to its source in a very user friendly way.

To set the *Association tag* and *Tag id*, first locate the IP address of each device (vehicle) in the list in the NAVconnect window then select one of either Hunter, Target1, Target2, Target3 or Target4 in the *Association tag* drop down list as appropriate to your system, then double click on the *Tag id* to rename it to a user friendly name (such as the colour or make and model of the vehicle). The information entered will pass through to the real-time display window as shown in Figure 54.

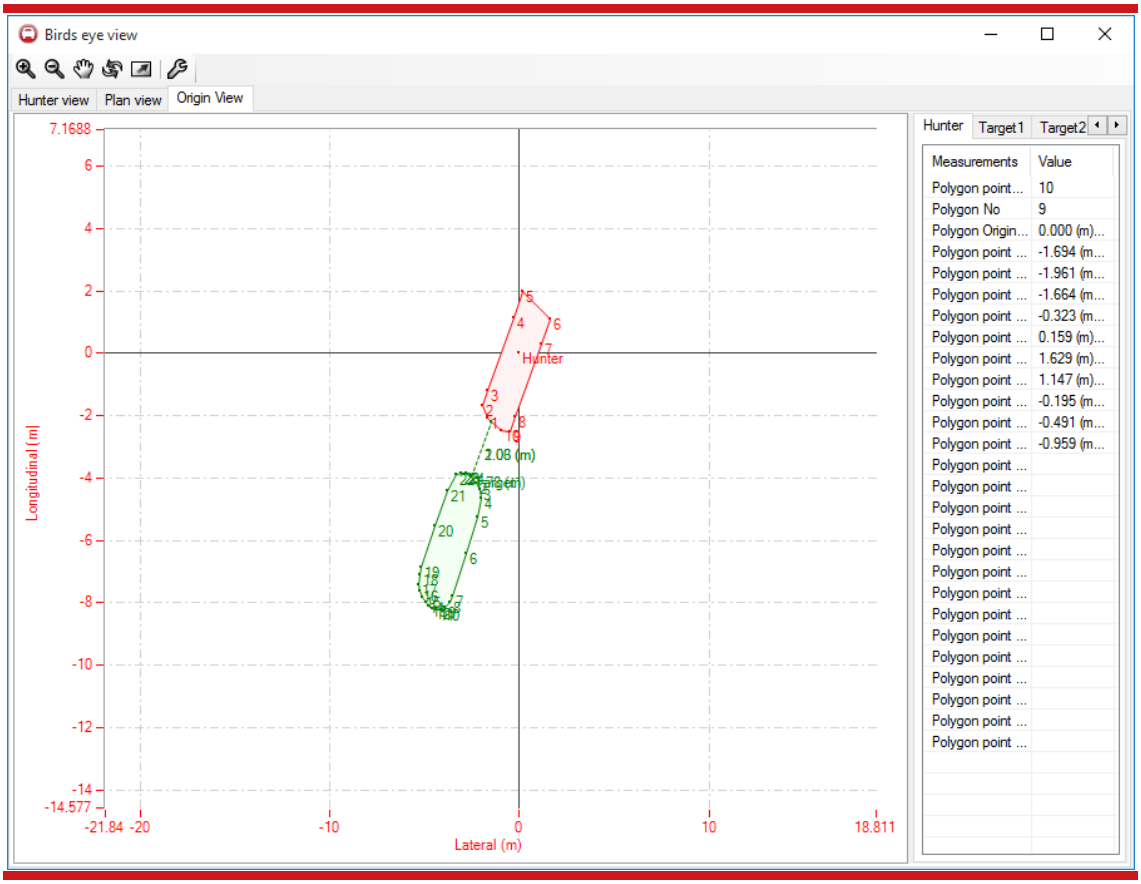
Figure 54. Real-time display with Tag id and Association tag



Bird's Eye View

The Bird's Eye View is part of the Display Data menu. It provides an aerial view of the test area, and is a good way to visualize where the hunter and targets, fixed points and map are in relation to each other. Figure 55 shows the Bird's Eye View window.

Figure 55. RT-Range Bird's Eye View



There are several icons that control the appearance of each tab in the Bird's Eye View. These are described in Table 14.

Table 14. Icon functions in the Bird's Eye View

Icon	Name	Description
	Zoom In	This icon is used to enter zoom in mode. Click and drag the mouse over the area to be zoomed.
	Zoom Out	This icon zooms out
	Pan	The icon is used to enter pan mode. Click and drag the mouse to pan the view.
	Refresh	This icon can be used to refresh the screen. When a target stops operating it will remain in view until it is refreshed.
	Auto Scale	This selects auto-scale where the scales of the graph will adjust automatically to keep all the items in view.
	Configure	This shows the configuration window for the Bird's Eye View.

The Bird's Eye View presents data in three different tabbed views called Hunter view, Plan view and Origin view.

The **Hunter view** tab offers a plan view based on the longitudinal and lateral distance between the object the view is centred on, and other objects. The *y*-axis is always aligned with the hunter vehicle's forward axis. To select which vehicle the view is centred on, click the Configure icon, then select a vehicle from the Display Mode tab of the Map Display Mode window as shown in Figure 56.

The **Plan view** tab is a useful view when working with feature points and fixed points.

The **Origin view** tab is especially useful view for ADAS testing as it shows the defined polygon for each vehicle in the test (including the hunter) as well as providing a visual indication of which points are being used for range measurements. In order to use the Origin view, local co-ordinates must be defined (see p.64)—if they are not the window will remain blank.

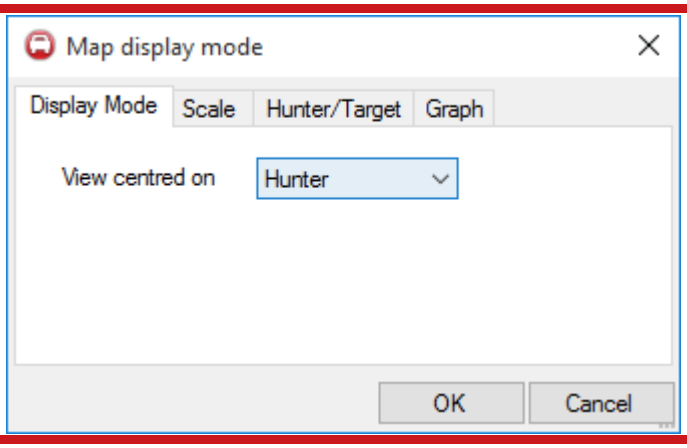
The Origin view can be centred on any vehicle in the test by clicking on the Configure icon, and selecting a vehicle from the Display Mode tab of the Map Display Mode window as shown in Figure 56. The axes are always aligned with the local co-ordinates axes.

The tabbed section on the right-hand side of the Bird's Eye View provides at a glance information about the vehicles under test. The information changes depending on which view is currently selected. The width of the window can be resized by placing your cursor on the window boundary and click-dragging. The widths of the columns within each tabbed section can also be adjusted in the same way.

View Configuration

Clicking on the configuration icon opens the Map Display Mode window. The settings selected here affect all three views in the Bird's Eye View—Hunter, Plan and Origin view.

Figure 56. RT-Range Bird's Eye View configuration



Display Mode. This tab allows you to choose which object the views should be centred on when the Auto Scale button is clicked.

Scale. By default each view is auto-scaled to show all objects. The Scale tab allows you to over-ride the default scaling by specifying the minimum and maximum values on each axis. The aspect ratio can also be preserved by selecting Preserve aspect ratio.

Hunter/Target. The Hunter/Target tab is used to set the display characteristics for each hunter and target. The caption text, position and colour can be adjusted using the controls in the Caption section. The caption text can be changed independently of the Tag id that is defined in NAVconnect. The selected colour also applies to the polygon fill and line.

The icon shape and colour used on the Hunter and Plan views can be also be defined.

The Polygon section houses the controls used to define the appearance of the polygon measurements, including the ability to disable the polygon point numbers and measurement markers. This can help reduce clutter in each view.

Save Data

The Save data option is used to store RT-Range, RT and CAN data to a file or files. The data is saved to binary formats called RCOM (RT-Range data), NCOM (RT data) and XCOM (RT and CAN data combined from a CAN enabled RT). If the device is outputting CAN data, the file extension will always be XCOM rather than NCOM.

The *Data logging* module logs the data from the Hunter, Targets and selected RT-Range as they appear in the NAVconnect window. The logged files will have their file names saved using the following format:

- *filename*-000_ *Tag id* [*Association Tag*].xcom

- *filename*-000_ *Tag id* [*Association Tag*].rcom

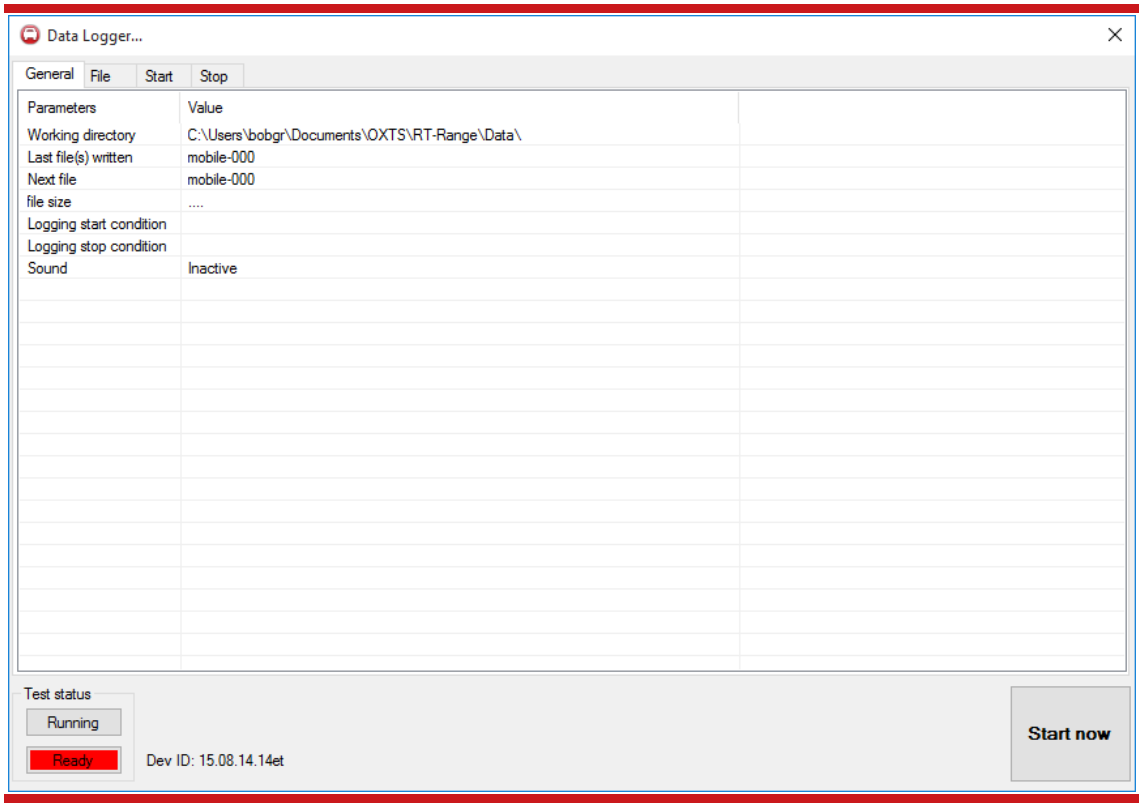
There will be a file logged for each of the enabled devices in the NAVconnect connection manager window.

Once all the data files have been logged, open the RCOM file using NAVgraph. NAVgraph will load all the files and display the RCOM, NCOM or XCOM data in graph form along with a table using a chosen template. From here, it is then possible to export all data to separate CSV files, or directly to a single CSV file. Please read the NAVgraph manual for more information about how to do this.

Note: RT-Range Post-Process does not currently support the XCOM file.

The Data Logging dialog box is shown in Figure 57.

Figure 57. RT-Range Data Logger



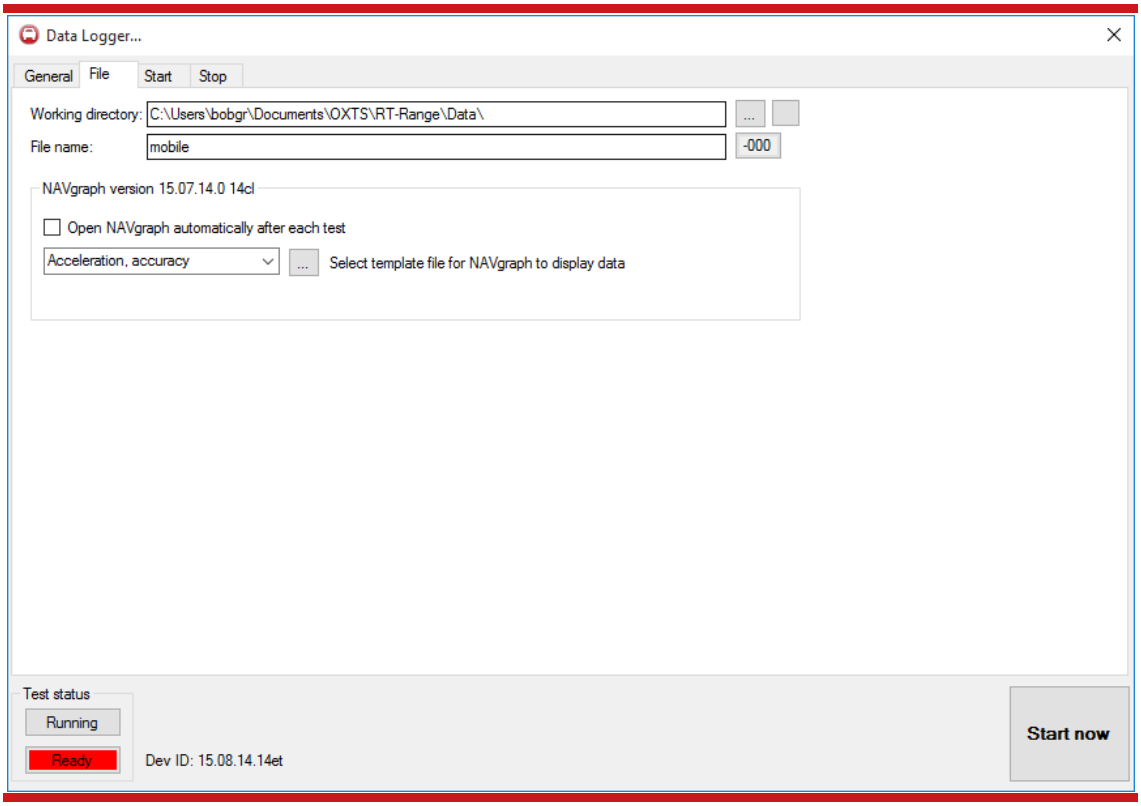
General tab. The General tab shows a summary of the logging. Descriptions of the parameters are shown in Table 15.

Table 15. Description of the General tab parameters

Parameter	Description
Working directory	Displays the directory where all test files will be saved
Last file(s) written	Displays the name of the last test file recorded
Next file	Displays the name of the next test file to be recorded
File size	Sum total of all the file sizes being logged combined
Logging start condition	Displays all options selected for starting the test.
Logging stop condition	Displays all options selected for stopping the test.
Sound	Displays whether any of the start or stop sounds are active

File tab. The File tab can be used to select the directory, file name and number of the next file to be written. The File tab is shown in Figure 58.

Figure 58. RT-Range Data Logger, File tab

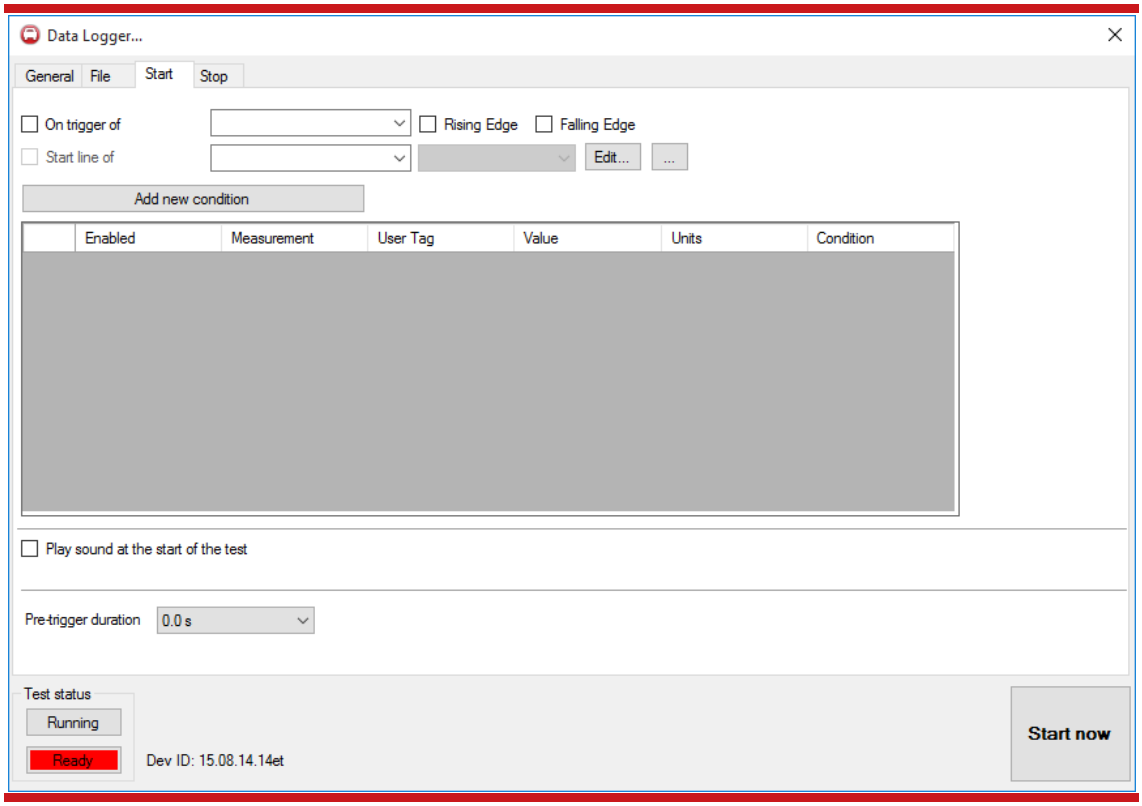


The “Working directory” is the directory where all the data will be saved. This can be changed by clicking on the “...” button to the right. An explorer window showing the files can be opened by clicking on the folder button.

The “File name” is the base name of the file that will be created. The window will automatically append a number to the end of the file. The number can be changed by clicking on the “-000” button. The number on this button will change as the file number changes. The number represents the *next* file to be written.

Start/stop tabs. The Start and stop tabs are used to set the conditions when a file will start and stopped being logged. The Start tab is shown in Figure 59.

Figure 59. RT-Range Data Logger, Start tab



Using the controls on each tab, it’s possible to build very specific conditions under which the Data Logger will record files. Logging can be started and stopped on the rising and/or falling edges of a specified RT’s trigger input, or when an RT crosses a defined line.

To define a start/finish line, click the Edit... button, then Define Start Line dialog box will open as shown in Figure 60. To define a start line, first enter a File name. Selecting an existing line will overwrite it with the new line. The “...” button is used to select a directory where the line files will be kept.

To use a line from an existing map, select one from the dropdown list in the Get Position From box. The "..." button can be used to select a directory where the maps are kept.

The position and heading of an RT can be used to define a line. In the Set start line at RT's position section, set the length of the start line and then click the Fix here ..." button. It is also possible to enter the latitude and longitude for the left and right ends by directly entering the latitude and longitude in the relevant sections.

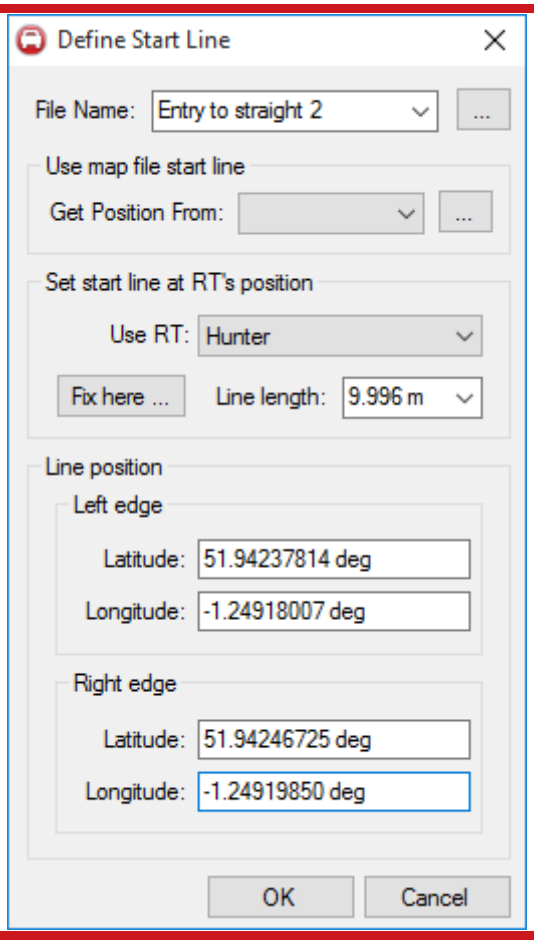
User defined conditions can also be created by selecting the Add new condition button and choosing a channel. The condition will be triggered when the channel rises above or falls below the entered value; or when it is over or under a certain value. Alternatively, a test can be manually triggered by clicking the Start now button

The Play sound at the start of the test option provides useful feedback when conducting tests and the driver's attention is focused elsewhere.

The Pre-trigger duration feature is used to capture a set amount of data prior to the start trigger—which is done by reading data back from an internal buffer. The data is then attached to start of the logged data.

When the logger is triggered, or manually started, the Running button in the bottom left-hand corner of the window turns red.

Figure 60. RT-Range Data Logger, Define Start Line



RT-Range Configuration Wizard

The RT-Range Configuration Wizard is accessed through the Real-Time Display. The parameters in the RT-Range Configuration Wizard are normally only changed when the system is installed in a vehicle.

Overview

In order to configure the RT-Range correctly the following information is required:

- IP Addresses of the RTs and of the RT-Range.
- Position(s) in the hunter vehicle of the sensors that measure the lane position.
- Positions of the sensors on all vehicles that measure the distance between the vehicles.

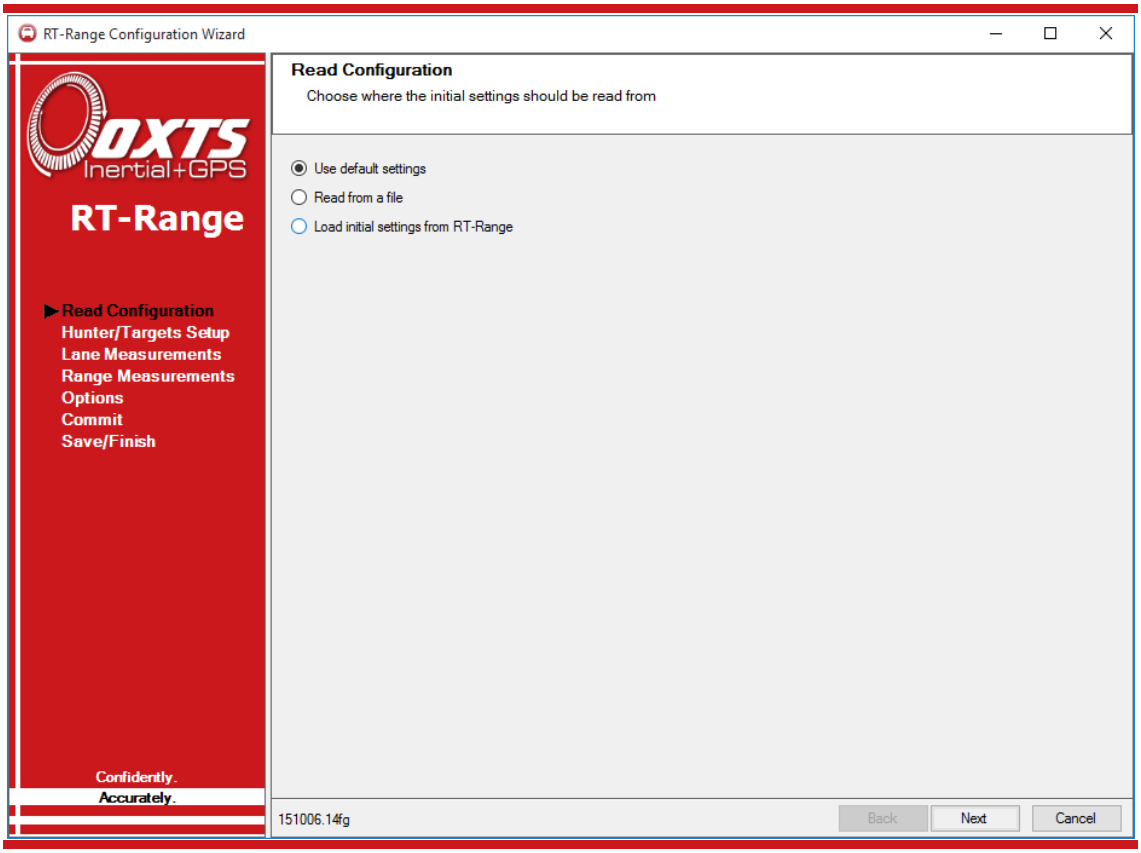
- Shapes of the target vehicles and fixed points, if polygons are going to be used.
- CAN bus, Local Co-ordinate Origin, Range Latency, etc.

The RT-Range is a very precise instrument and these measurements are critical to getting the best results from it. It is not easy to get all of the measurements accurate to 1 cm or better. However, a 1 cm error on the RT-Range configuration will result in a 1 cm error in the outputs. It is critical to get these measurements accurate.

Reading the Initial Configuration

Figure 61 shows the first page of the wizard.

Figure 61. Read Configuration page of the RT-Range Configuration Wizard



The initial settings that the wizard displays can come from several sources:

Default Settings. If this option is selected then the wizard will start with a default set of values. The current values in the RT-Range will be lost when these new values are committed.

Read from a file. If this option is selected the wizard will read all the settings from a file on the disk. This can be used to store the configuration from several vehicles and quickly restore a particular vehicle's settings.

Load initial settings from RT-Range. This option connects to the RT-Range over Ethernet and loads the settings that are currently programmed to the RT-Range.

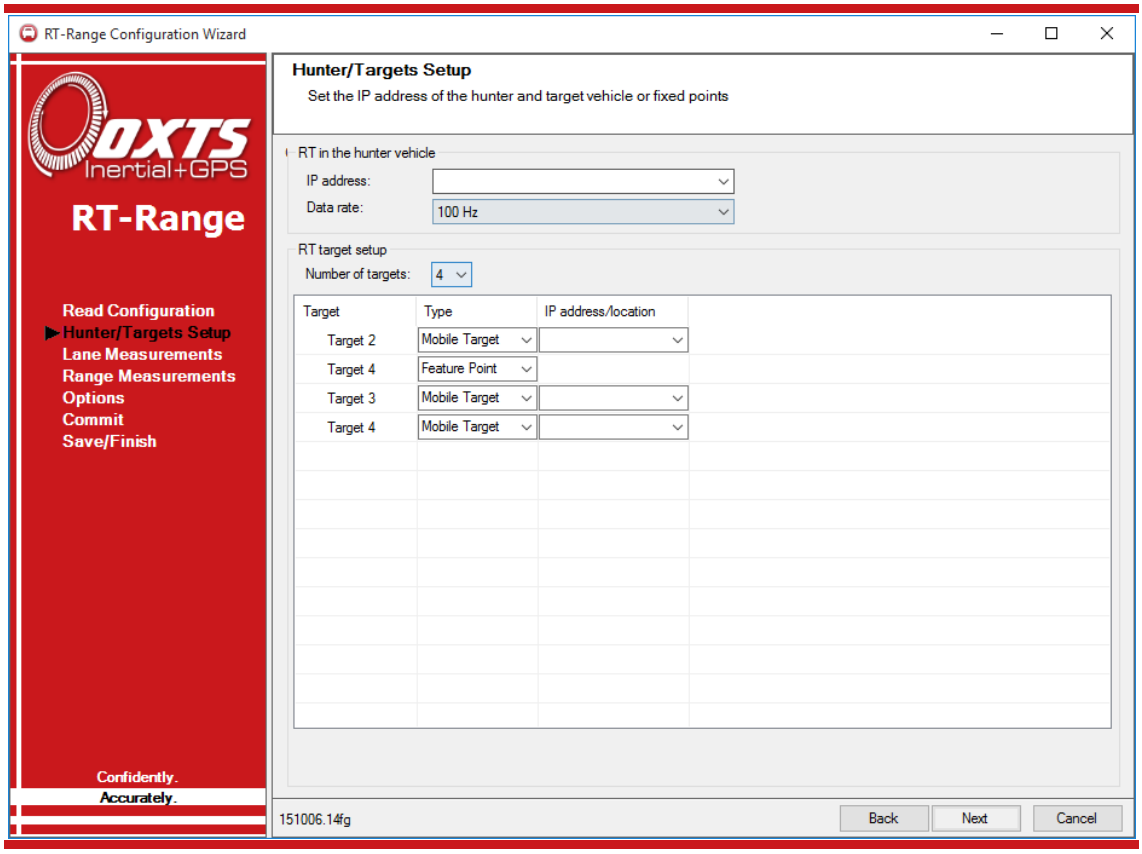
After selecting the source for the initial settings click Next.

Hunter/Targets Setup

The RT-Range needs to know the IP addresses of the RTs in the hunter and target vehicles so it can pick up the correct data via Ethernet. The IP addresses of the RTs will be shown on the delivery note that came with the RTs. The IP address selection boxes list the RTs that have been found on the network.

Figure 62 shows the Hunter/Targets Setup page of the Wizard where the IP addresses are selected.

Figure 62. RT Addresses RT-Range Configuration Wizard



After selecting the IP address of the RT in the hunter vehicle, select the data rate of that RT. For an RT3000 select 100 Hz; for an RT4000 select 250 Hz. For RT2000 products, select the output rate of the product being used.

Up to four targets can be defined in the RT target setup area. First, choose the number of targets you wish to define. These will then appear in the lower window, ready for further configuration.

For each target, the system needs to know its type (Mobile Target, Fixed Point or Feature Point). Mobile Targets are attached to a specified IP address. Fixed Point targets are defined by position—either by entering the lat/lon, heading and altitude directly, or by reading an offset position from an RT that is available on the network.

When one of the targets is defined as a feature point, a Feature Point File can be defined at the bottom of the window. Click the "…" button to choose its location. For more information on using fixed points or feature points, see the Quick Configuration page for fixed points or feature points.

It is not possible to change the number of targets without resetting the RT-Range. If you intend to use one target at the start of the test, then have more targets later on, it is best to define all the targets at the start and ignore the extra outputs until you need them.

It is possible to have more than one target with the same IP address. The RT-Range can then configure each of the targets separately even though they are using the information from the same RT.

Lane Measurements

The RT-Range calculates lane position measurements from three different locations on the vehicle. These locations are configured relative to the RT output. Figure 63 shows the typical positions on the vehicle where the lane position measurements are made.

Figure 63. Typical positions for points ABC on a vehicle

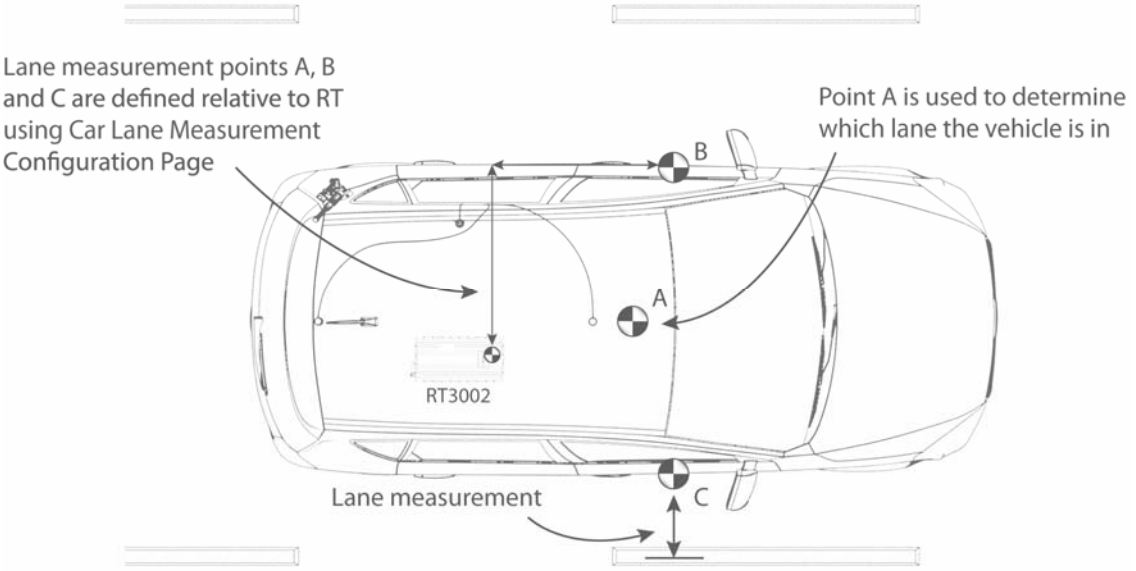
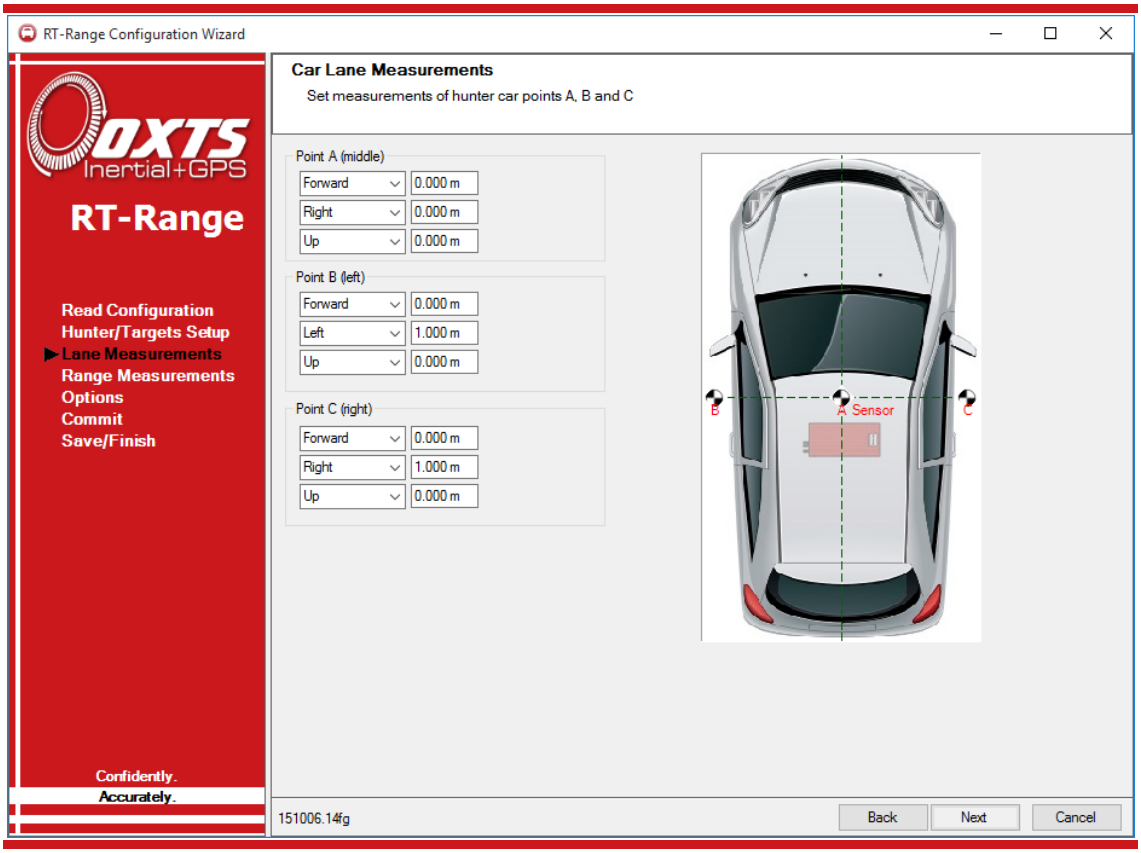

Lane measurement points A, B and C are defined relative to RT using Car Lane Measurement Configuration Page
Point A is used to determine which lane the vehicle is in
B
A
RT3002
Lane measurement
C

Figure 64 shows the page in the RT-Range Configuration Wizard that configures points A, B and C.

Figure 64. Car Lane Measurements in the RT-Range Configuration Wizard



The measurements are from the displaced output position of the RT to Point A, B or C. For best results you should not use the Displace Output option of the RT as this can be confusing.

The measurements are in the *vehicle co-ordinate frame*. These are the co-ordinates that you have configured the RT to use in the Orientation page of the RT configuration software.

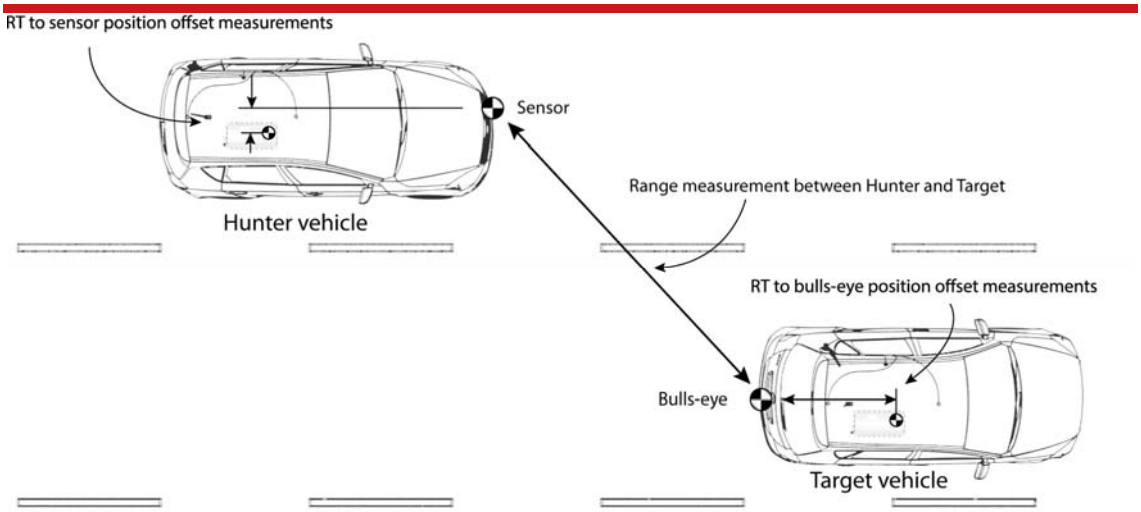
It is essential to make these measurements accurate. This is not easy with a tape measure. Unless the measurements are made accurately the RT-Range cannot be accurate.

Measurements are always displayed in metres but can be entered in inches or feet as well. For inches add “in” to the end of the number and for feet add “ft” to the end of the number. For example, “11.3 in” would be interpreted as 11.3 inches or 0.287 m.

Range Measurements

Range measurements between a hunter and target can be made using polygons or a single point—depending on how they have been configured. We call the single point on the hunter a *sensor* and a single point on a target is called a *bulls-eye*.

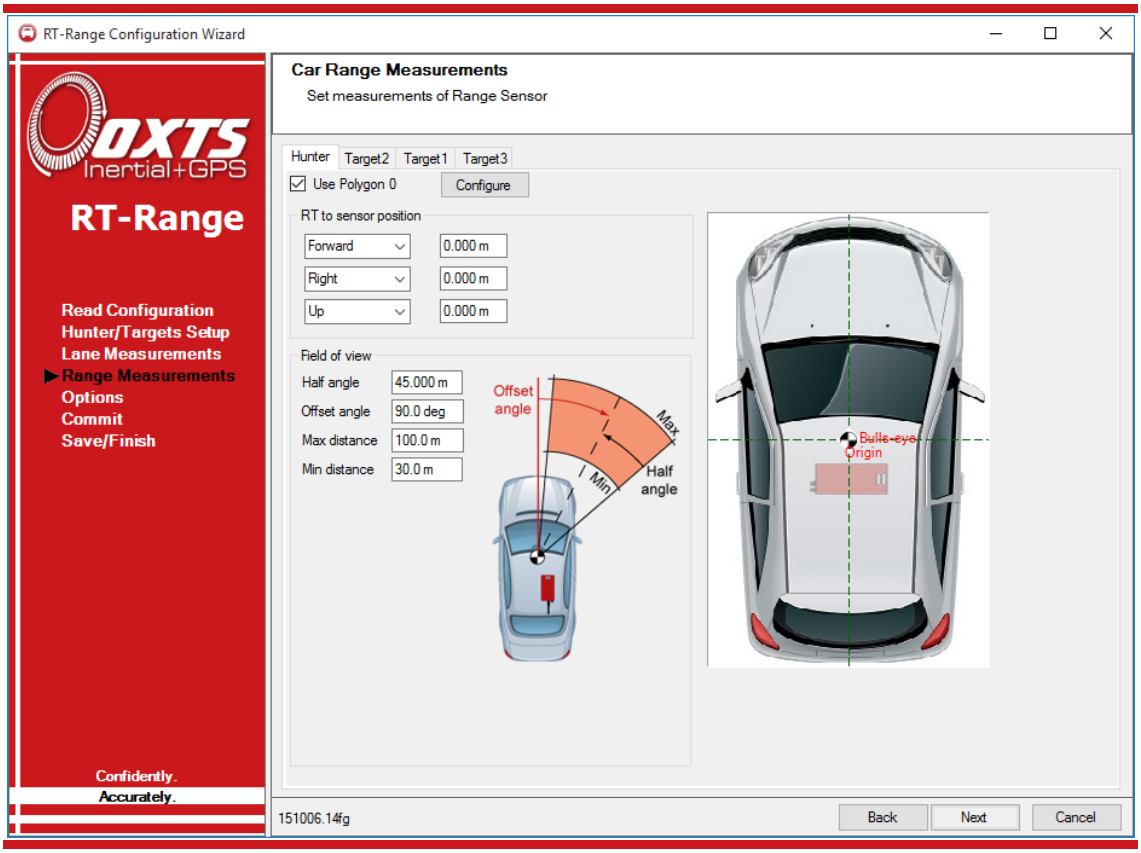
Figure 65. Typical Positions for Sensor and Bulls-eye Points on the Vehicles



If the hunter and target are configured as a sensor and bulls-eye, then range measurements are calculated between those two points. If a hunter is configured as a polygon but the target is configured as a bulls-eye, then range measurements are calculated from a single vertex on the hunter's polygon, or a linear point between two vertices and the target's bulls-eye. If the hunter and target are both configured as polygons, then range measurements reflect the shortest distance between each polygon perimeter.

If one of the targets has been setup as a feature point, an additional tool allows a field of view to be setup. Feature points become active only when they fall within the defined field of view. This does not affect *how* feature point measurements are made, it only affects *when* they are made.

Figure 66. Range Measurements, Hunter tab



Note the number of Target tabs reflects the number of targets that have been defined on the Hunter/Targets Setup page.

Figure 66 shows the Hunter configuration tab (including the Field of view). By default the hunter is defined as a sensor. The position of that sensor, relative to the RT in the hunter, is defined using the controls in the RT to sensor position section. The terms forward, right and up refer to the vehicle co-ordinate frame.

For peace of mind, the relative position of the sensor is shown on the diagram (note this is just a guide, and not to scale or accurate). It is essential to make these measurements accurate. This is not easy with a tape measure. Unless the measurements are made accurately the RT-Range cannot be accurate.

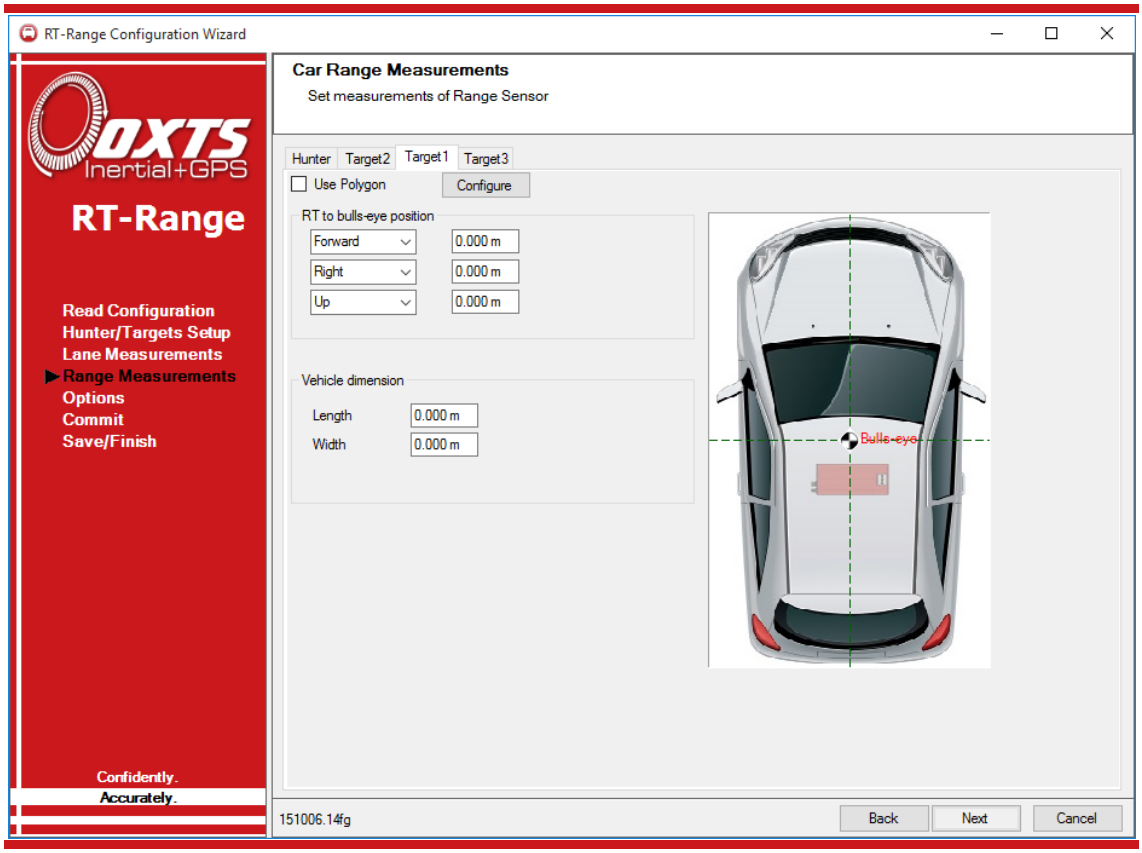
To define the hunter as a polygon, select the Use Polygon option. The Polygon window will open automatically. You can re-open this window at any time using the Configure button. For detailed information on defining polygons, see Defining polygons on page 84 for details.

If any of the targets on the Hunter/Target Setup page are defined as feature points, the Field of view section will be visible on the Hunter tab. The maximum range for the field of view is 500 m, in both real-time and post-process. Care should be taken when using a large field of view range with a high number of feature points in a small area.

This may be too much for the processor in real-time and may require more CPU time for the RT-Range system, causing delays. However, there should be no adverse effects if post-processing the data.

When feature points become active the RT-Range provides its usual comprehensive list of real-time information on each one. This includes longitudinal, lateral and resultant range, forward and lateral time to collision of each target as well as the Feature Point ID. When feature points leave the Field of view the RT-Range does not show the measurements to these feature points anymore unless they re-enter the field of view.

Figure 67. Range Measurements, Target tab



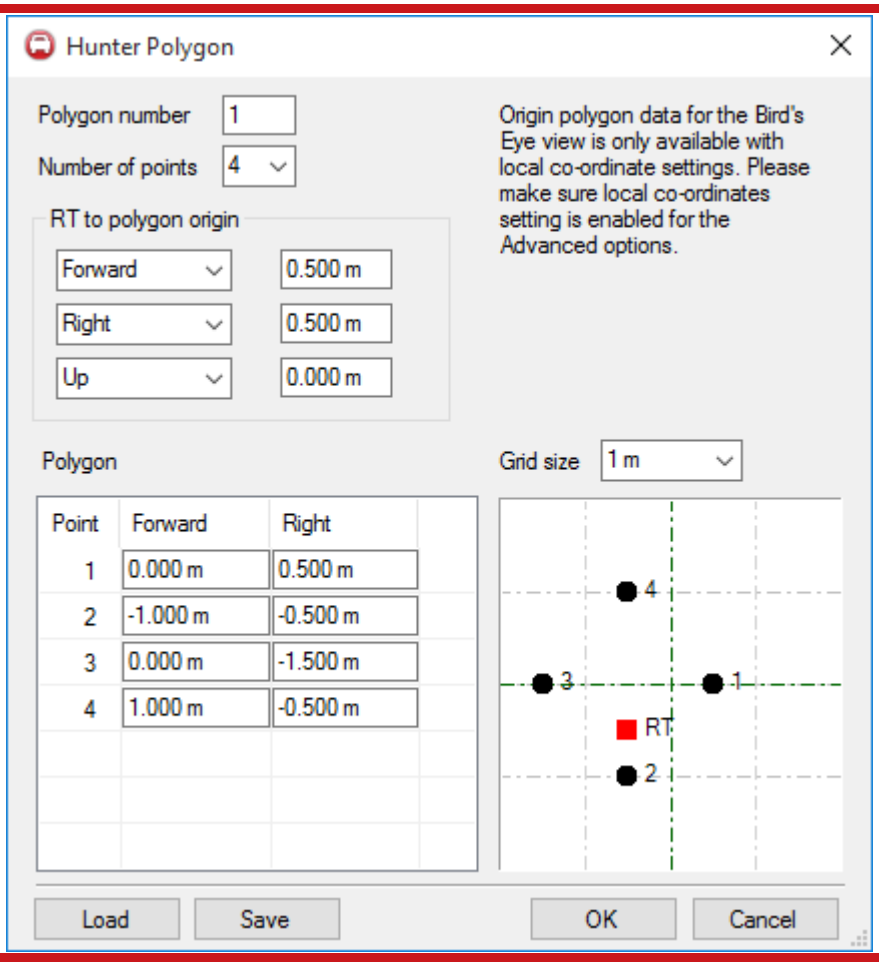
The target configuration tab is almost identical to the Hunter tab and is configured in the same way. By default, a target is defined as a bulls-eye, unless the Use polygon option is selected.

The main difference is the Vehicle dimension tab that is found on Target tabs. The length and Width fields are not used by the RT-Range software. They are passed through the software and provide an extra mechanism for the user to identify which vehicle was being used as a target during the tests.

Defining polygons

Polygons, whether they are for a hunter or target, are defined in a window similar to the one shown in Figure 68. This window is used to tell the RT-Range how many points make up a polygon shape, where the RT's measurement origin is in relation to the polygon point's origin, and where each polygon is.

Figure 68. Polygon definition window



Polygon number: The polygon number field is used to identify the polygon being used on the CAN bus. The RT-Range passes this number to the user via the CAN bus without using it or modifying it. Unfortunately the CAN bus does not easily support text fields.

Number of points: The number of points used to create each polygon ranges from 3 to 24. In terms of range measurements, the RT-Range will interpolate linearly between

vertices, so you only need to add enough points to define the desired shape. Select the number or points you wish to use using the Number of points box.

RT to polygon origin: To define each point or vertex that will make up a polygon, you need to enter a two-dimensional Cartesian co-ordinate. The *y*-axis of the co-ordinate system is aligned to the vehicle's longitudinal axis (positive forwards); the *x*-axis of co-ordinate system is aligned to the vehicle's lateral axis (positive right). However, the system needs to know where the origin of your measurements is, with respect to the RT in that particular vehicle. The controls in the RT to polygon origin allow you to describe where your measurement origin is in relation the RT installed in that vehicle.

Polygon: The lower half of the window is dedicated to the polygon shape. On the left-hand side is a list of numbers where the co-ordinates of each point can be entered. To the right is a visual representation of the resultant shape. The Grid size menu can be used to increase the visibility in the window when working with large polygons.

It does not matter if the points are added in a clockwise or anti-clockwise way, but they should be entered consecutively. Do not add the front left point, followed by the rear right point for example—shapes that cross are not supported. Concave shapes should also be avoided.

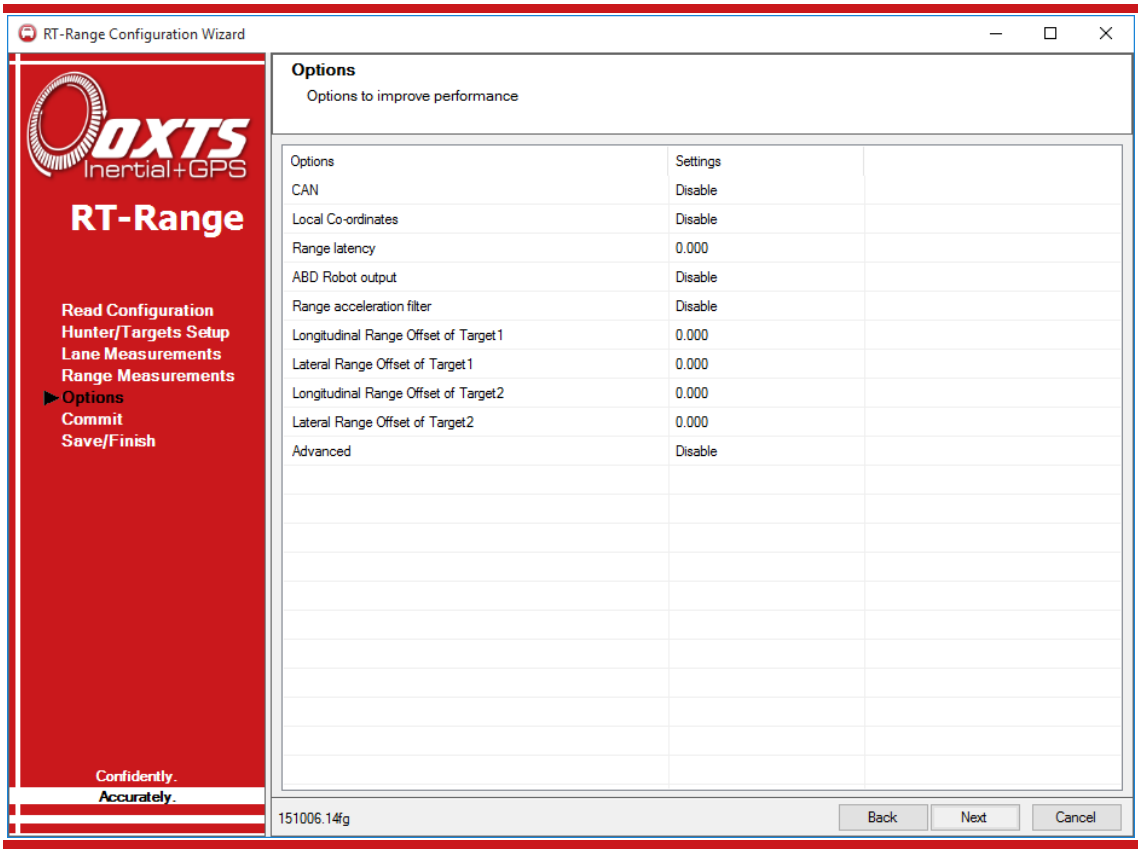
A red square is used to represent the relative position of the RT installed in the vehicle. This is useful to confirm that the offset you have specified in the RT to polygon origin section is correct.

Load/Save: Polygons can be saved to and loaded from files using the Load and Save buttons. If you often use the same car, it is quicker to load the polygon shape then check the RT to polygon origin is still valid.

Options

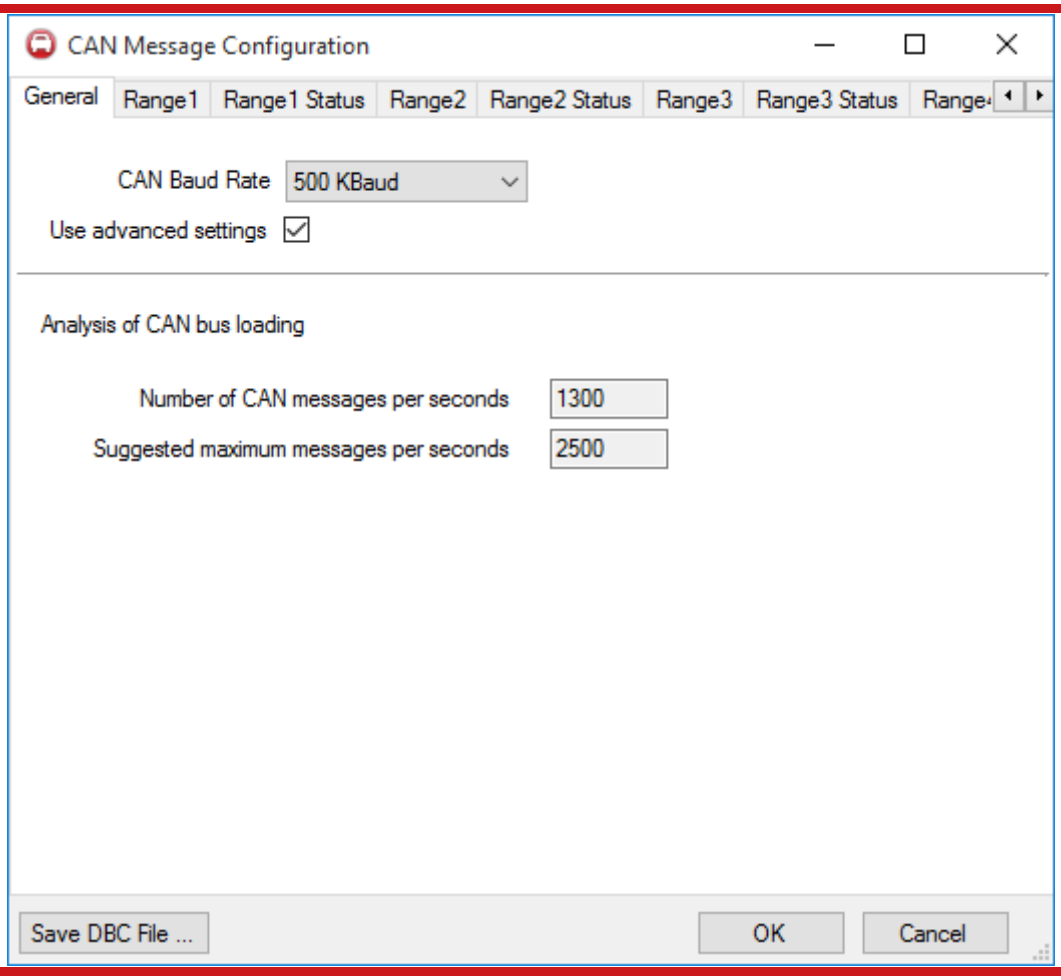
The Options page is used to configure the RT-Range options. Figure 69 shows the Options page of the RT-Range Configuration Wizard. Each of the options are described below. To edit options, click in the settings column.

Figure 69. Options in the RT-Range Configuration Wizard



CAN. The CAN option sets the CAN baud rate for the RT-Range or disables the CAN bus output. The CAN setting must match the CAN setting for the bus that you are connecting to.

Figure 70. CAN Message Configuration



When advanced settings are not used the CAN bus will output a default set of CAN identifiers. As there are now so many potential CAN messages it is almost always essential to use advanced settings and choose the messages that are needed. The "Save DBC File…" option can be used to save the correct DBC file for this configuration; this applies to both when the normal or advanced settings are used.

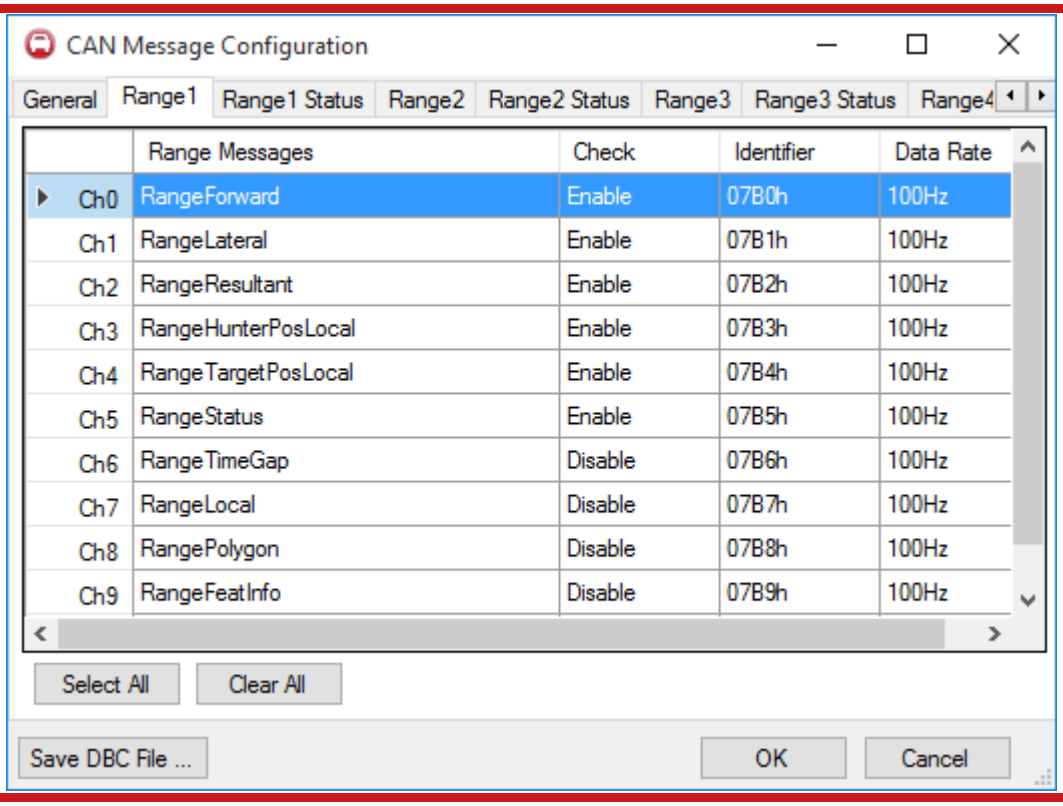
When advanced settings are selected, the Range, Lane and Target pages are accessible, as shown in Figure 71. These pages control how the Range, Lane and Target CAN messages are output. The identifiers and data rates can be controlled.

If fewer targets are configured on the Hunter/Target Setup page then fewer Range and Target pages will be visible.

It is very easy to overload the CAN bus using the RT-Range. The CAN bus is not fast enough to communicate all the range, lane and target messages. The number of messages that have been configured is shown on the General tab. An advisory limit for the current CAN bus is also shown, however the limit may be far less than this if there

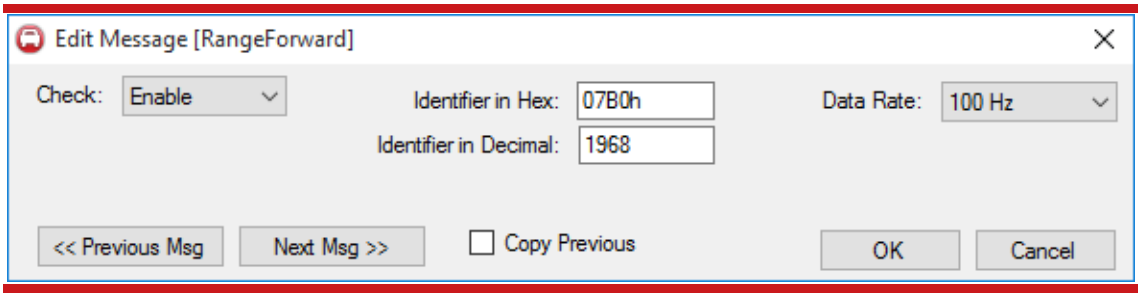
are many other sensors on the CAN bus. Typically ADAS testing has many other sensors so take care not to overload the bus.

Figure 71. Range Messages



On the Range tab all the settings for the range output messages are listed. The message can be enabled or disabled; the identifier can be changed and the data rate can be set. To adjust the options double click on the message that you want to change. Figure 72 shows the "Edit Message" dialog box.

Figure 72. Edit Message



Note: please exercise caution when using the "Copy Previous" function. If each message is copied incorrectly it may the stop CAN output from working correctly.

Using the Edit Message dialog box, you can advance through the messages in the list quickly by clicking on << Previous Msg or Next Msg>>. If you wish to copy the previous or next message from the list into the currently selected field, you must first select the Copy Previous box—you can then advance through the list changing each message, previous or next, as you go. This is a quick way to edit all the messages in sequence but care must be taken to do so accurately.

Figure 73 shows the target navigation messages, which can be configured in the same way as the range messages. Figure 74 shows the target status messages.

Figure 73. Configurable CAN messages for target navigation messages

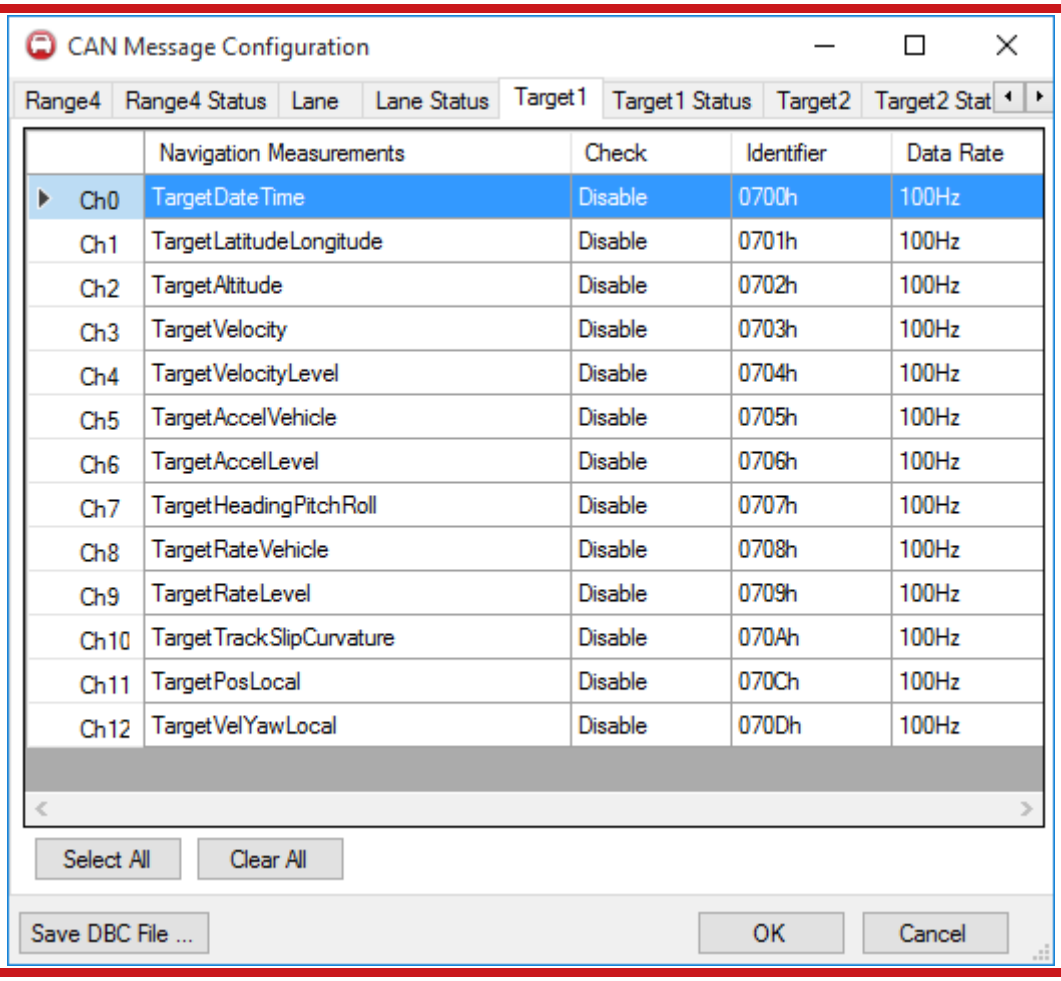
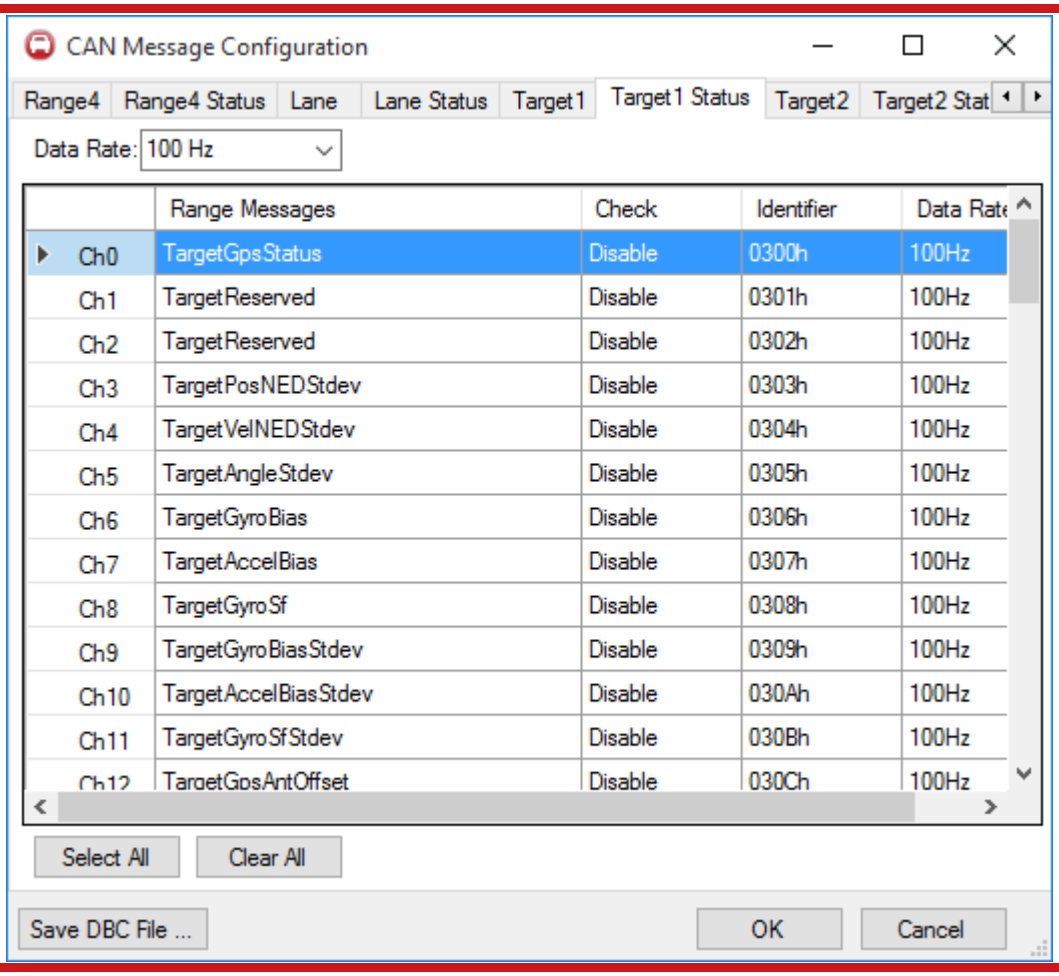


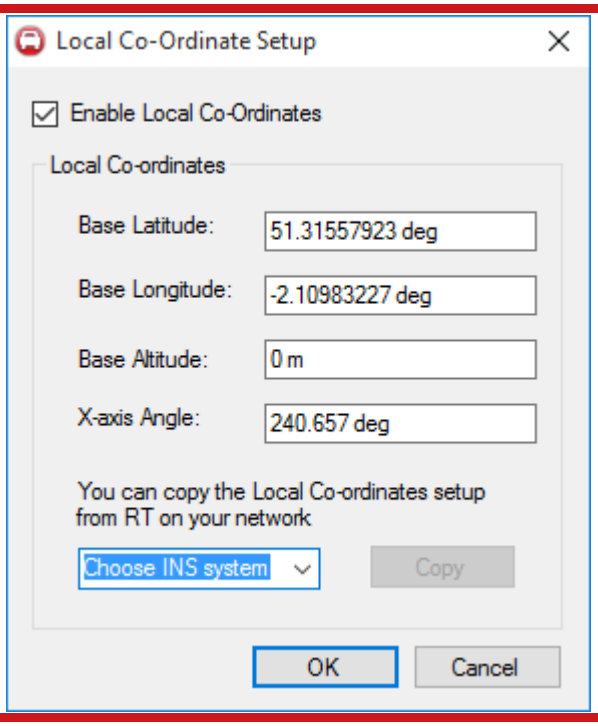
Figure 74. Configurable CAN messages for target status messages



The target status messages are configured slightly differently compared to the other messages. The Ethernet transmission from the RT to the RT-Range does not transmit every status message every 100 Hz (or 250 Hz) cycle; instead only one status message is transmitted each cycle. The RT-Range will apply the same principle. Only one status message will be transmitted each cycle at the data rate that is selected. If packets are dropped by the radio (wireless LAN) from the RT to the RT-Range then these messages will not be predicted or interpolated, they will not be output or an older version will be output.

Local Co-ordinates. The RT-Range includes the option to output the position of the hunter and target vehicles in a local co-ordinate system. This is often easier than using latitude and longitude. The local co-ordinates of the hunter and target vehicles are output on the CAN bus. Figure 75 shows the Local Co-ordinates dialog box.

Figure 75. Local Co-ordinate setup in the RT-Range Configuration Wizard



The Local Co-ordinates translate the curved earth into a grid that is locally flat. The transformation cannot do this accurately over a large range (in fact no transformation can) and the Local Co-ordinates should only be used over a small area, up to about 10 km square.

You must provide the position in latitude and longitude, and altitude, of the origin of the grid. This is the position where the X and Y values will be zero. You can also specify the angle of the *x*-axis for the grid. Normally the *x*-axis will be north and the *y*-axis will be west. However, sometimes it is easier to have the *x*-axis (and therefore the *y*-axis) in a different direction. The *x-axis Angle* field can be used to specify the direction of the *x*-axis relative to north; for example a value of 90 degrees will mean that the *x*-axis points east.

Note that, normally the RT has the *z*-axis pointing down. For the Local Co-ordinates the *z*-axis points up. This is so the position plots in the same way as a map. (You don't normally look at maps from below and, if you did, the directions would be wrong).

Range Latency. Measurements from the target vehicles are transmitted via Wireless LAN or via radio. This inevitably leads to some delay in the measurements from the target. So that the RT-Range can output without any delay, the position and velocity of the target vehicle has to be predicted. This prediction can lead to small errors during acceleration transients (jerks). The prediction has no error when the acceleration is constant.

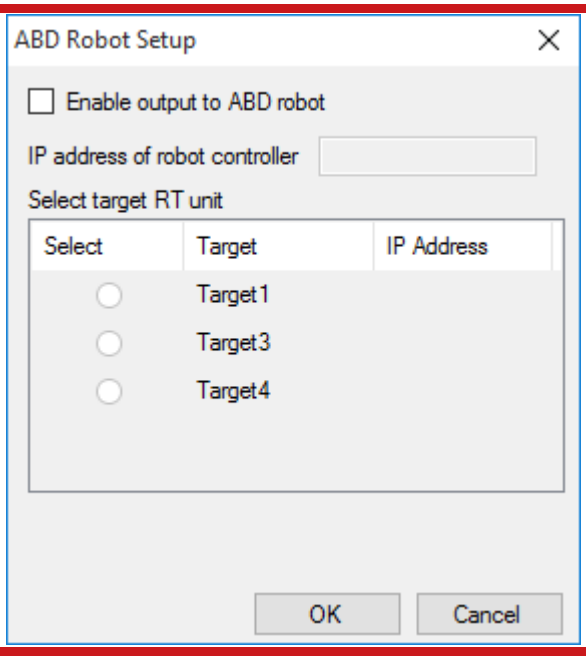
To avoid or reduce the problems of jerk, the range output of the RT-Range can be delayed. This delay allows the communication link(s) to transmit the data and, therefore, no prediction is required. The delay is constant and is chosen by the user. If the communication link(s) still have not transmitted the data when the output is scheduled then the target vehicle's measurements will be predicted (though by a smaller amount than a zero latency system would use).

The delay in the outputs is set using the Range Latency option.

This setting has no effect on the lane position measurement. The lane position measurements will always be output in real-time with no delay.

ABD Robot Setup. If the RT-Range is being used to output data to an ABD steering robot then it will need to be configured so that the correct information is sent to the robot. Figure 76 shows the ABD Robot Setup dialog box.

Figure 76. ABD Robot Setup dialog box



The standard IP address for the ABD steering robot is 195.0.0.100. The robot is able to trigger tests based on one target. For example, it can trigger a test when target 3 is within 30 m of the hunter vehicle. Choose which target measurements should be sent to the robot. Targets can be either mobile targets or fixed points.

Note that the RT-Range connects the Ethernet in one vehicle to the Ethernet in the other vehicle. When there are two robots, one in each vehicle, then the RT-Range cannot be connected to both robots unless the IP address of the robot is changed. There is a safety risk if care is not taken when using two robots. Make sure you understand

which RT-Range and which RT is sending data to which robot and how it is getting there.

Later versions of the RT-Range and robot software are able to identify problems by identifying the serial number of the RT in the robot software. Older versions cannot do this and it is essential to get the configuration right.

Range acceleration filter. The Range acceleration filter window allows the relative acceleration between hunter and individual targets to be filtered. The accelerations are filtered before they are used in any calculations. One tab is shown for each defined target. Once Enable Range acceleration filter has been selected, it is possible to choose from one of five different filters:

- General
- Butterworth
- Bessel
- Chebyshev (0.5 dB)
- Chebyshev (2.0 dB)

The Cut off frequency of each filter can be defined as well as the Damping ratio of the General filter. The effects of the filter are summarised in the lower half of the Acceleration filter window.

Note that, if the data from the target has too many dropped packets because of the radio then the filter will automatically be reset. The RT-Range will fill in occasional dropped packets and try to maintain the filter.

Longitudinal Range Offset of Target... The Longitudinal Range Offset is normally configured using the Quick Config, Longitudinal Offset page. It can be configured here too. This value will show the value that is *committed* to the RT-Range. If the value has not been committed using the Longitudinal Offset page, but is being used until the RT-Range is reset, then the real-time value will not be read from the RT-Range.

The Longitudinal Range Offset will be added to the longitudinal range that has been computed. This allows for small adjustments to the longitudinal range that is output.

Lateral Range Offset of Target... The Lateral Range Offset is normally configured using the Quick Config, Lateral Offset page. It can be configured here too. This value will show the value that is *committed* to the RT-Range. If the value has not been committed using the Lateral Offset page, but is being used until the RT-Range is reset, then the real-time value will not be read from the RT-Range.

The Lateral Range Offset will be added to the lateral range that has been computed. This allows for small adjustments to the lateral range that is output.

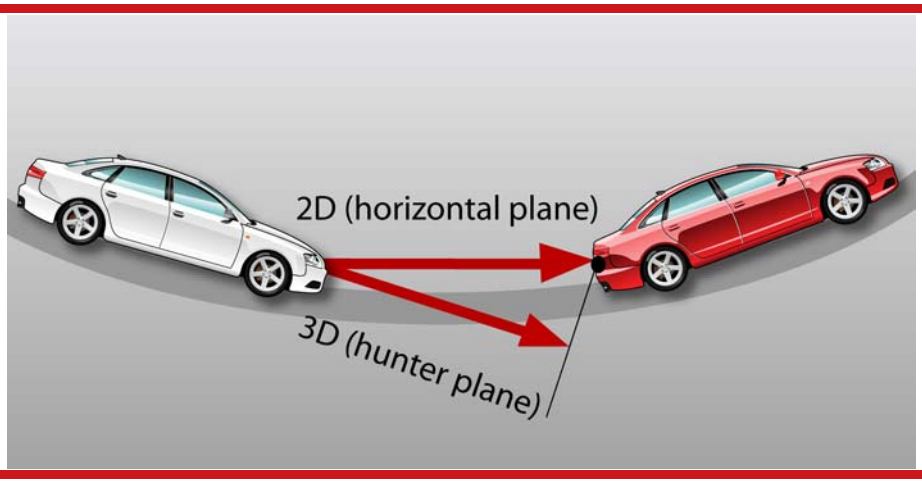
Advanced. The advanced option box is used for sending advanced commands to the RT-Range and is normally used for testing. There are some advanced commands that the user may want to configure. Table 16 lists some of the advanced commands that may be useful.

Table 16. Advanced commands

Command	Description
-range1_meas_plane_hunter -range2_meas_plane_hunter -range3_meas_plane_hunter -range4_meas_plane_hunter	These commands are used to change the measurement plane used for each target from the horizontal plane (2D) to the hunter plane (3D). Figure 77 shows the difference diagrammatically. Further explanation is available in the Calculation Details section (page 127) at the end of the manual.
-target1_rate[xx.x] -target2_rate[xx.x] -target3_rate[xx.x] -target4_rate[xx.x]	These commands are used to advise the RT-Range of the expected data rate for the target. They are essential when using the acceleration extrapolation filter (below).
-range1_extrapol_filt[x.x]_[y.y]_[z.z]_[a.a]_[b.b] -range2_extrapol_filt[x.x]_[y.y]_[z.z]_[a.a]_[b.b] -range3_extrapol_filt[x.x]_[y.y]_[z.z]_[a.a]_[b.b] -range4_extrapol_filt[x.x]_[y.y]_[z.z]_[a.a]_[b.b]	These commands are used to set an acceleration filter that is used to extrapolate the position and velocity of the target vehicle when real-time data is not needed. It is essential to set the expected target data rate when using these commands.
-can_timeref_gps -can_timeref_utc	These commands configure the CAN target time messages output by the hunter to be with reference to GPS time or UTC time. By default the target time messages are with reference to GPS time.

NAVconfig does include filter design for the angular acceleration filter. Other coefficients can be computed using NAVconfig, read from the mobile.cfg file and then transferred to the RT-Range advanced commands.

Figure 77. Range measurement plane

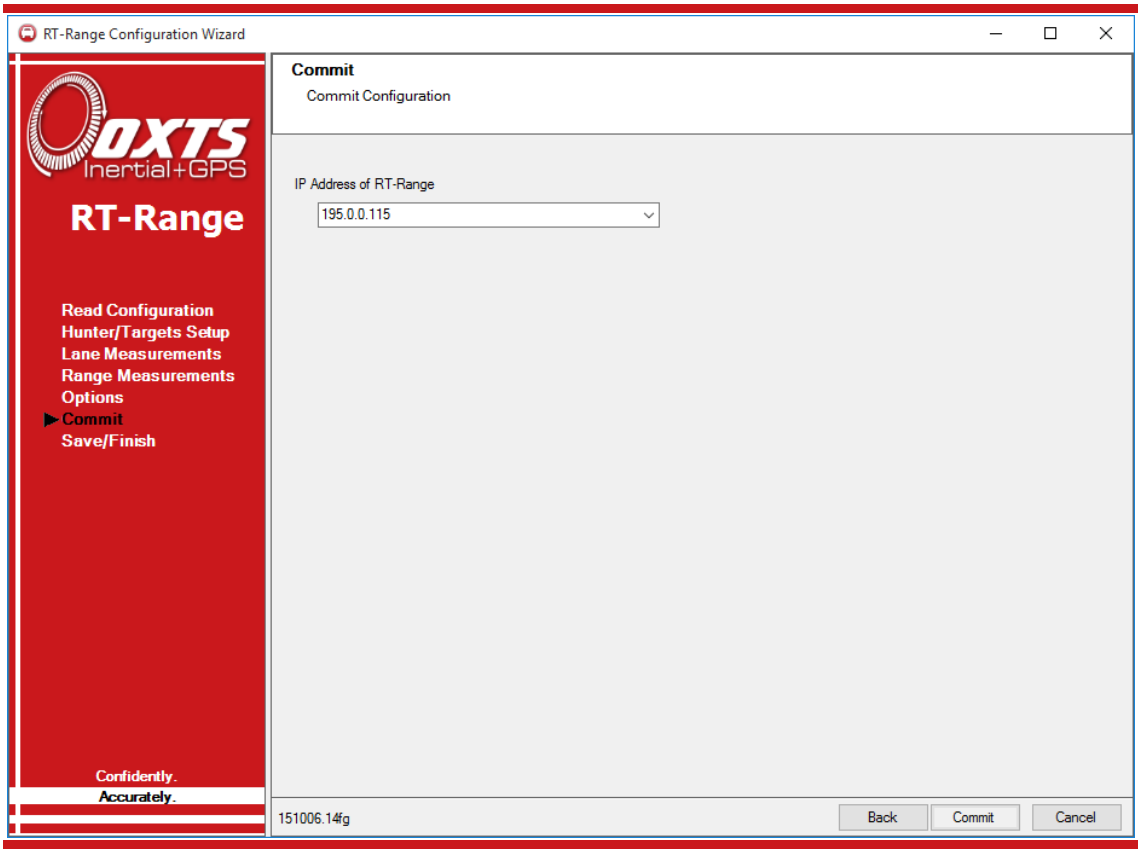


Committing the configuration to the RT-Range

The commit screen allows you to send the configuration to the RT-Range system. The IP address of the RT-Range is required for this. The IP address is usually 195.0.0.*n* where *n* is the serial number of the RT-Range. The IP address is marked on the delivery note.

Figure 78 shows the Commit page of the RT-Range Configuration Wizard.

Figure 78. Commit page in the RT-Range Configuration Wizard

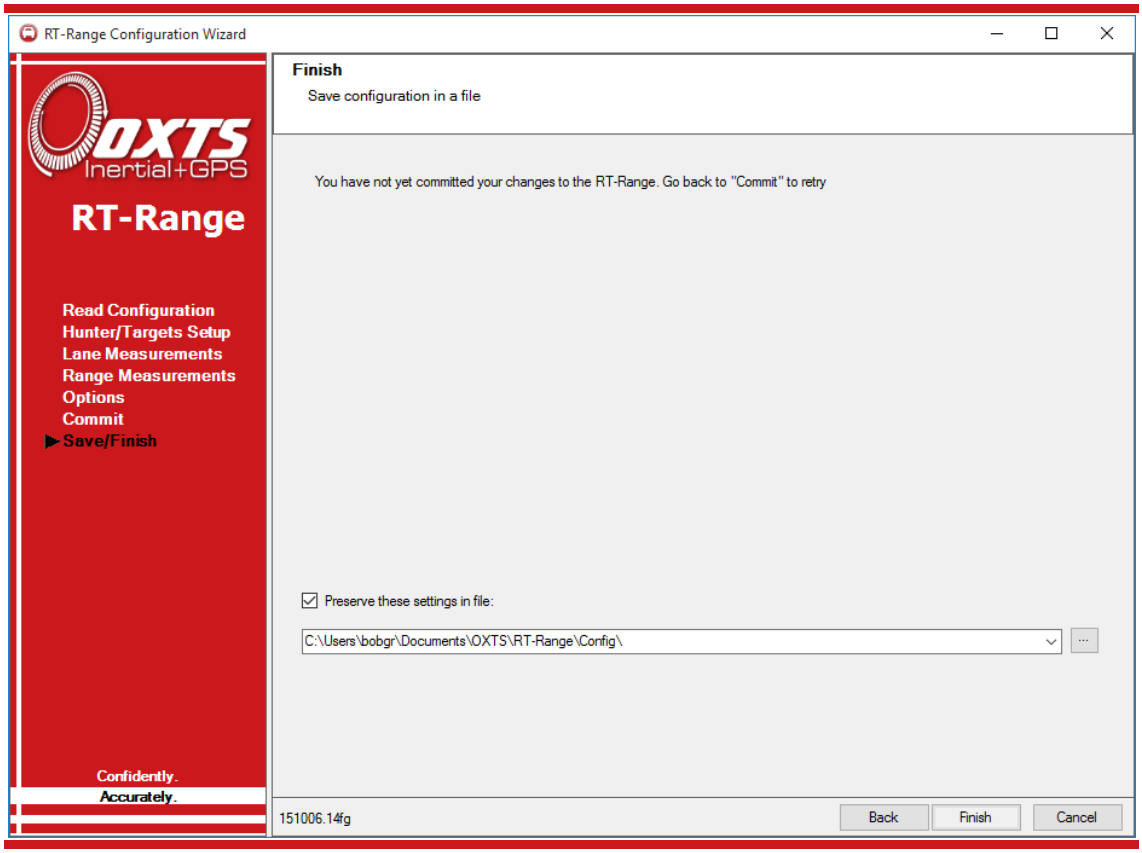


The RT-Range will automatically reset after the settings are committed. It takes about 40 seconds for the RT-Range to reboot.

Saving a copy of the RT-Range configuration locally

Before finishing, it is possible to save a copy of the settings in a file on the local computer. This is useful for storing configurations for several vehicles or several setups on one vehicle. The Finish page also lets you know if the settings have been committed successfully to the RT-Range system or not. Figure 79 shows the Finish page.

Figure 79. Finish page in the RT-Range Configuration Wizard



To save a copy of the setting in local file check the Preserve these setting in file check box and enter the filename. The RT-Range software will make the folder automatically if it does not exist.

RT-Range Post Processing Wizard

The RT-Range Post Processing wizard is used to reprocess the NCOM files of hunter and target vehicles and extract the lane position or range measurements in CSV file format. This might be required if the communication link was not installed, failed to work or the results are required without prediction. It can also be used to reprocess the data using different settings (for example, different positions for Points A, B or C.)

The RT-Range Post Processing Wizard can also be used to convert RCOM files to text. The RCOM file can be recorded in real-time or made by post-processing NCOM files.

Overview

There are one or two stages required for post-processing. If the NCOM files are not available for every vehicle then it will be necessary to post-process the RD files that are

recorded in the RTs. Once all the NCOM files are available the RT-Range Post Processing wizard can be used to convert the NCOM files to RCOM and then to CSV.

Figure 80 and Figure 81 show the two stages of the workflow. The RD files are logged internally in the RT; these can be downloaded and reprocessed using the RT Post-process software. There is no need to use the RT Post-process software to convert the NCOM file to CSV. Alternatively the NCOM file can be logged by a separate PC in each vehicle using Enginuity; this means you do not need to post-process the RD files.

Figure 80. Workflow to convert RD files to NCOM files

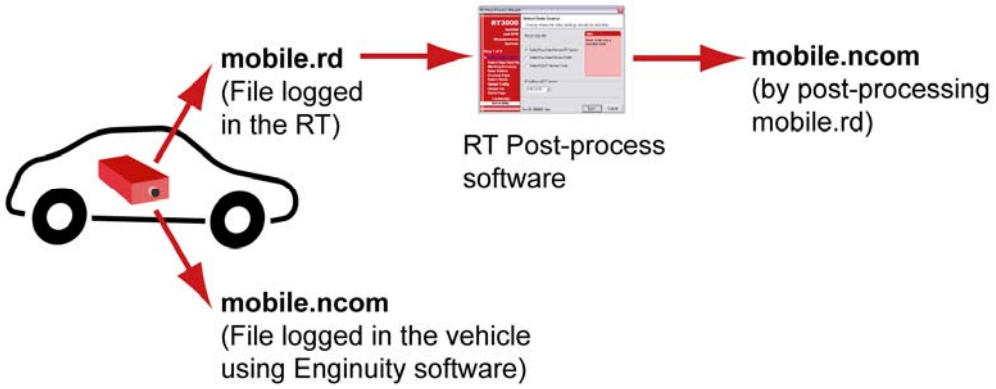
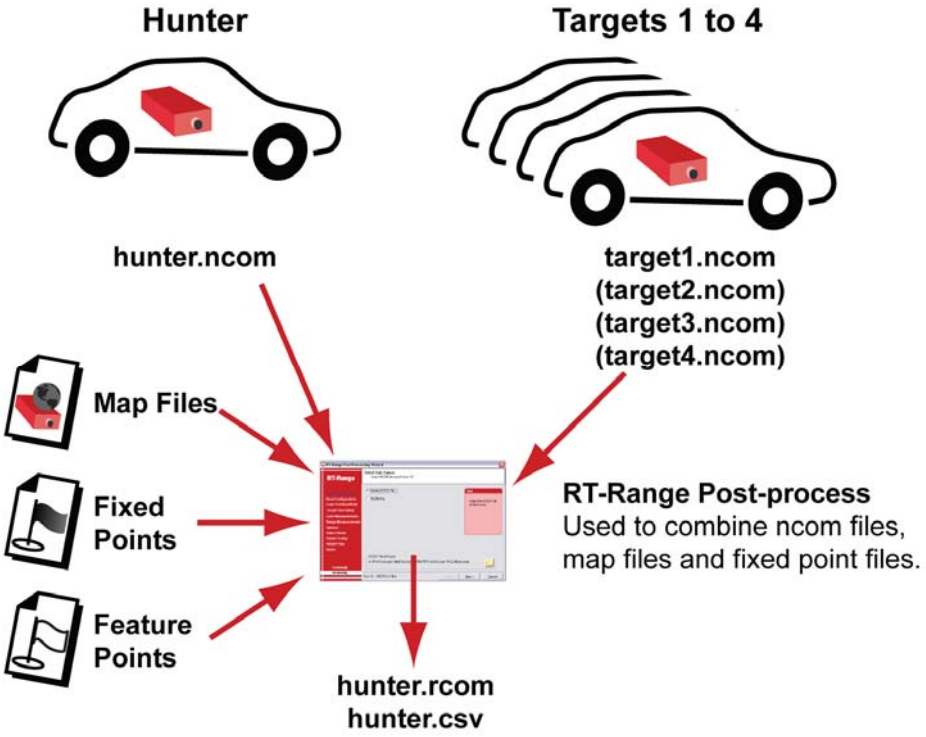


Figure 81. Workflow to convert NCOM files to RCOM and CSV files



Once all the NCOM files are available the RT-Range Post Process software can be used to combine them together. The settings can be changed; one of the target vehicles can be used as the hunter so that measurements in the reference frame of the target vehicle can be obtained; different maps and fixed points can be selected.

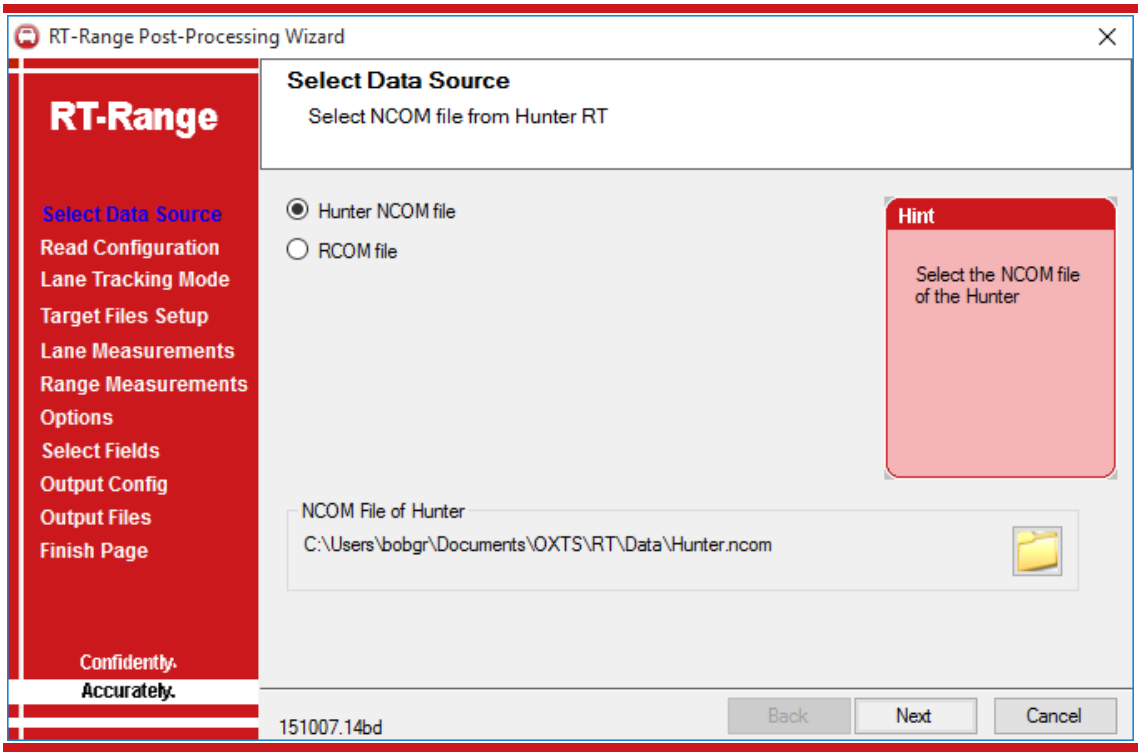
The RT-Range Post-process software outputs an RCOM file, just like the file logged by the Real-time Display. It can export this RCOM file to CSV format so that it can be loaded in to Excel, Matlab or other software packages.

The RT-Range Post-Processing wizard can also be used to convert captured RCOM files and turn them in to CSV format. When an RCOM file is selected then the wizard will jump directly to the Select Fields page.

Select Data Source

To reprocess the data using RT-Range Post-process it is essential to have an NCOM file from the hunter vehicle; Figure 82 shows the screen for selecting the NCOM file from the hunter vehicle. If an RCOM file is available then it can be exported to CSV format but the parameters used for processing the data cannot be changed.

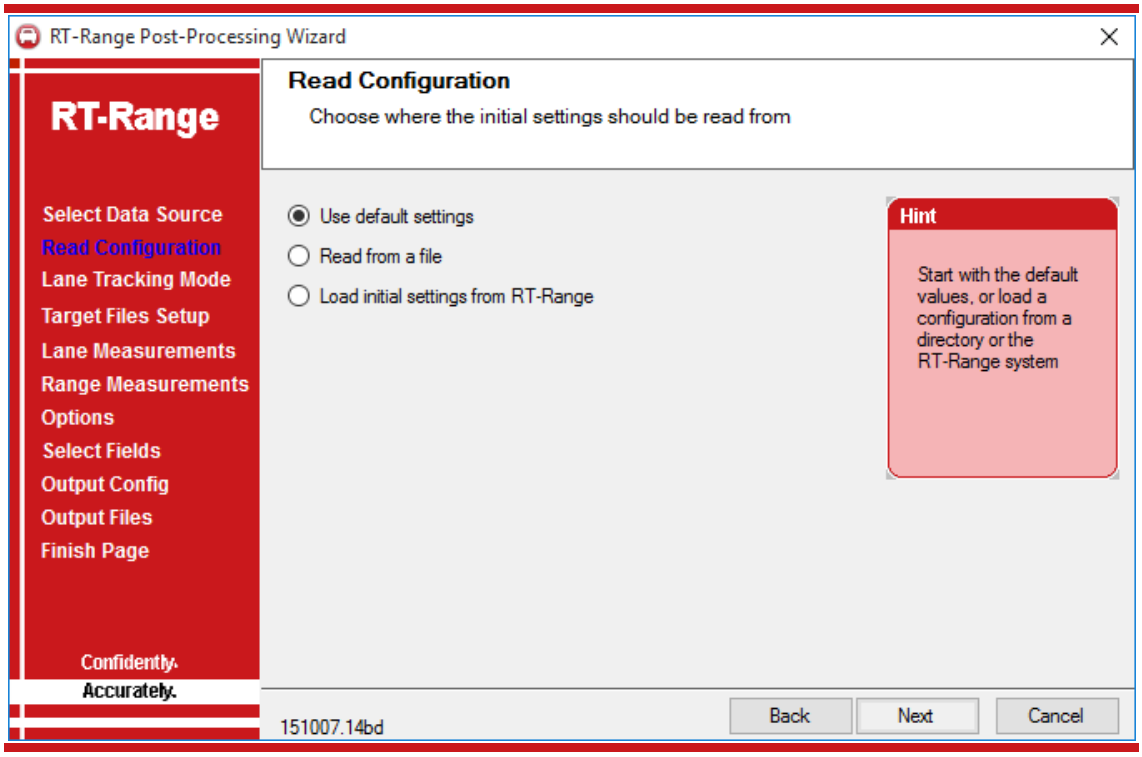
Figure 82. Hunter NCOM file selection in the RT-Range Post-Processing Wizard



Read Configuration

If you have saved a configuration in a file, or if you want to use the configuration that is stored in your RT-Range, then you can load these in to the RT-Range Post-Processing wizard. Figure 83 shows the read configuration options in the RT-Range Post-Processing wizard.

Figure 83. Read Configuration in RT-Range Post-Processing Wizard



Default Settings. To use the default settings select the radio button. The lane and range settings will contain the default settings that the RT-Range system was delivered with.

Read from file. The range and lane parameters will be read from the defined `RTRange.cfg` file. To select a different configuration file use the browse button to select a different file.

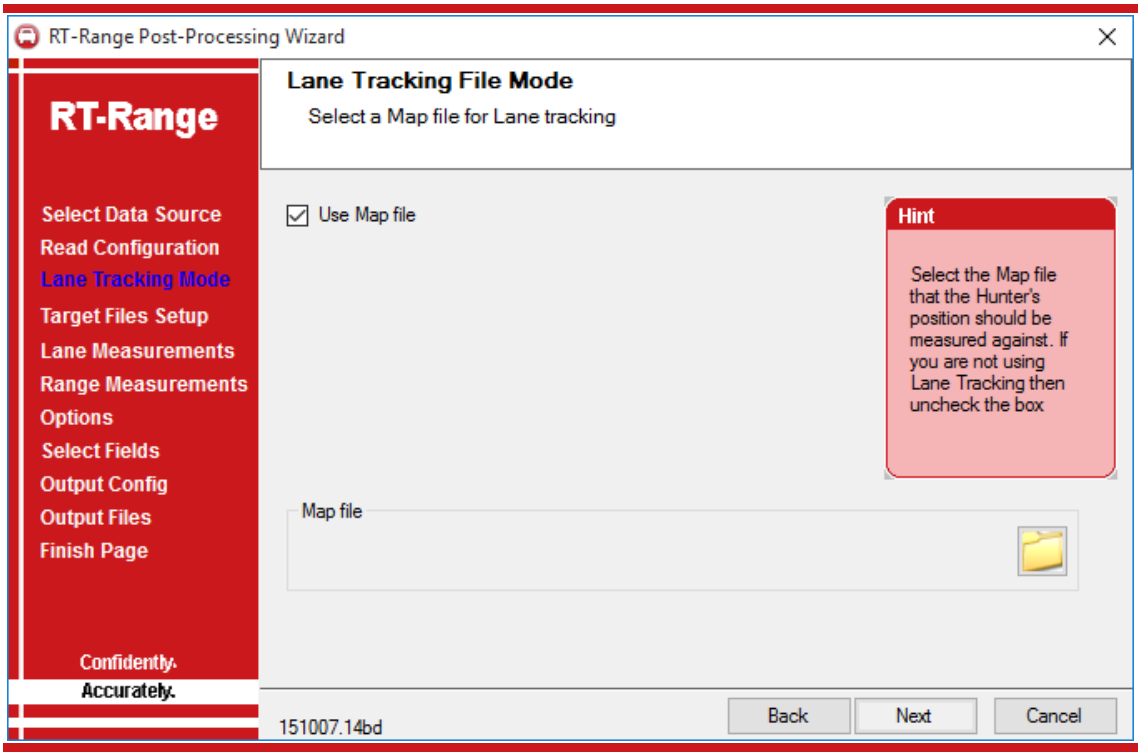
Load Initial Settings from RT-Range. To use the same settings as the RT-Range system select the radio button and make sure the RT-Range system is connected to the network via Ethernet. Enter the correct IP address in the edit box to download the configuration file from the RT-Range hardware.

Lane Tracking Mode

The RT-Range Post-Processing wizard can compare the position of the hunter vehicle to the lane markings. Check the *Use Map File* checkbox to perform the lane position measurements and select a map file.

Figure 84 shows the Lane Position File Mode Page of the RT-Range Post-Processing wizard.

Figure 84. Lane Position Map file selection in RT-Range Post-Processing Wizard

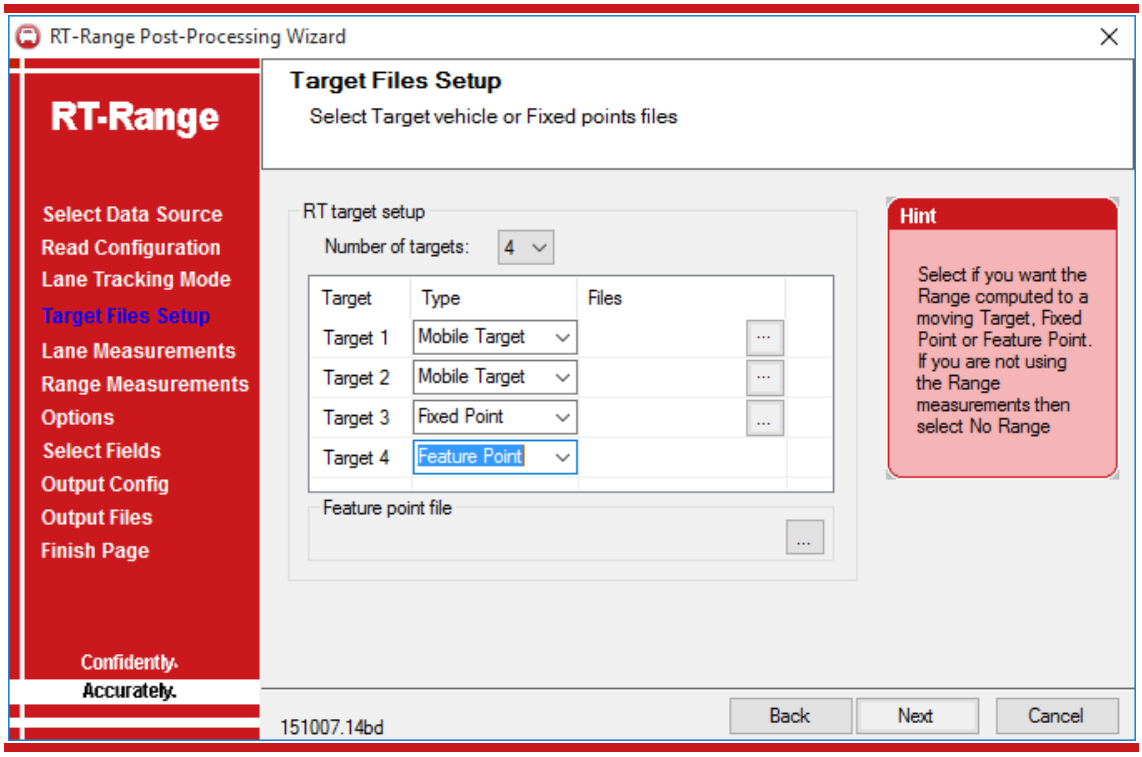


Target Setup

The RT-Range Post-Processing wizard can compute the range from the hunter vehicle to fixed points or to target vehicles. Either a fixed point file or a target NCOM file is required to do this. The range mode can be disabled so that no range measurements are output.

Figure 85 shows the Target Files Setup page of the RT-Range Post-Processing wizard.

Figure 85. Target Files Setup page in the RT-Range Post-Processing Wizard



Select the number of targets using the "Number of targets" dropdown list.

Mobile Target. To compute the range from the hunter vehicle to a mobile target select Mobile Target from the dropdown list and select the associated target NCOM file.

Fixed Point. To compute the range from the hunter vehicle to a fixed point select Fixed Point from the dropdown list and select a fixed point file. The fixed point file has to be saved using the Real-Time Display software.

Feature Point. To compute the range from the hunter vehicle to a feature point select "Feature Point" from the dropdown list and select a feature point file (*.FTL).

Lane Measurements Setup

This is the same configuration page as the car lane measurements in the RT-Range Configuration wizard. It is provided so changes can be made to the positions of points A, B and C in post-processing. This page will only be shown by the wizard if a map file has been selected, otherwise it will be skipped.

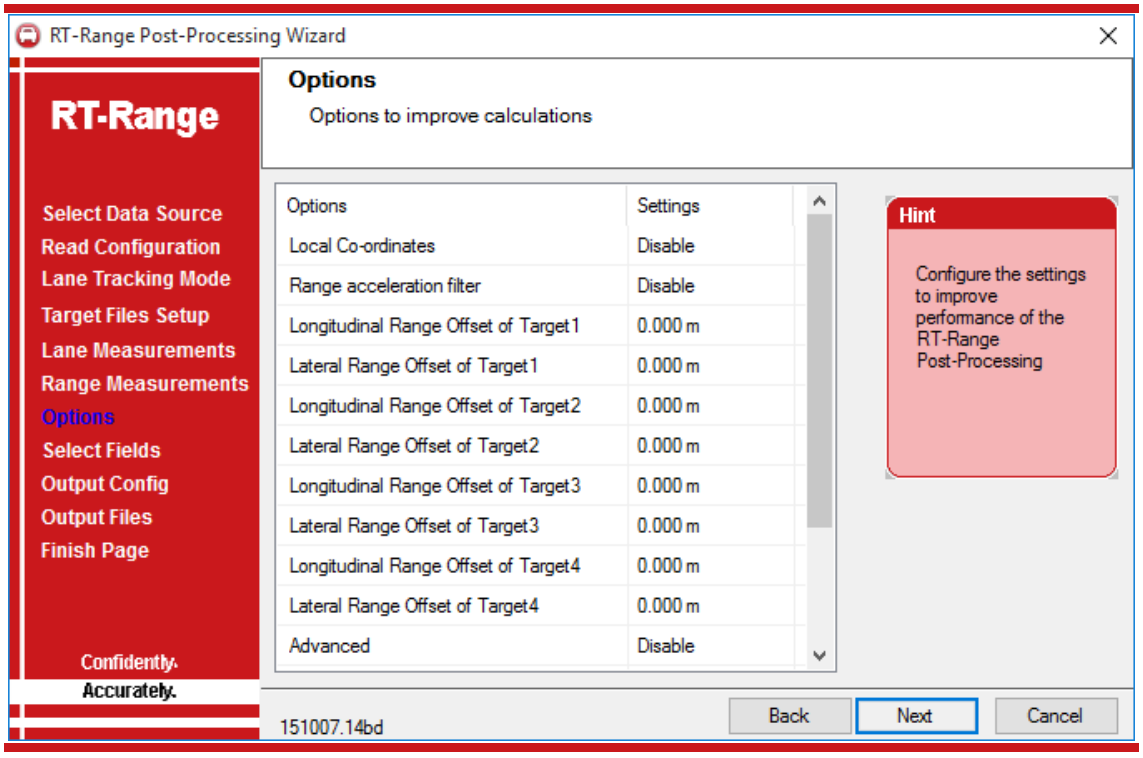
Range Measurements

This is the same configuration page as the car range measurements in the RT-Range Configuration wizard. It is provided so changes can be made to the positions of the sensor, bulls-eye and polygon in post-processing.

Options

Figure 86 shows the Options page of the RT-Range Post-Processing wizard.

Figure 86. Options page in the RT-Range Post-Process Wizard



These options behave in the same way as the RT-Range Configuration wizard.

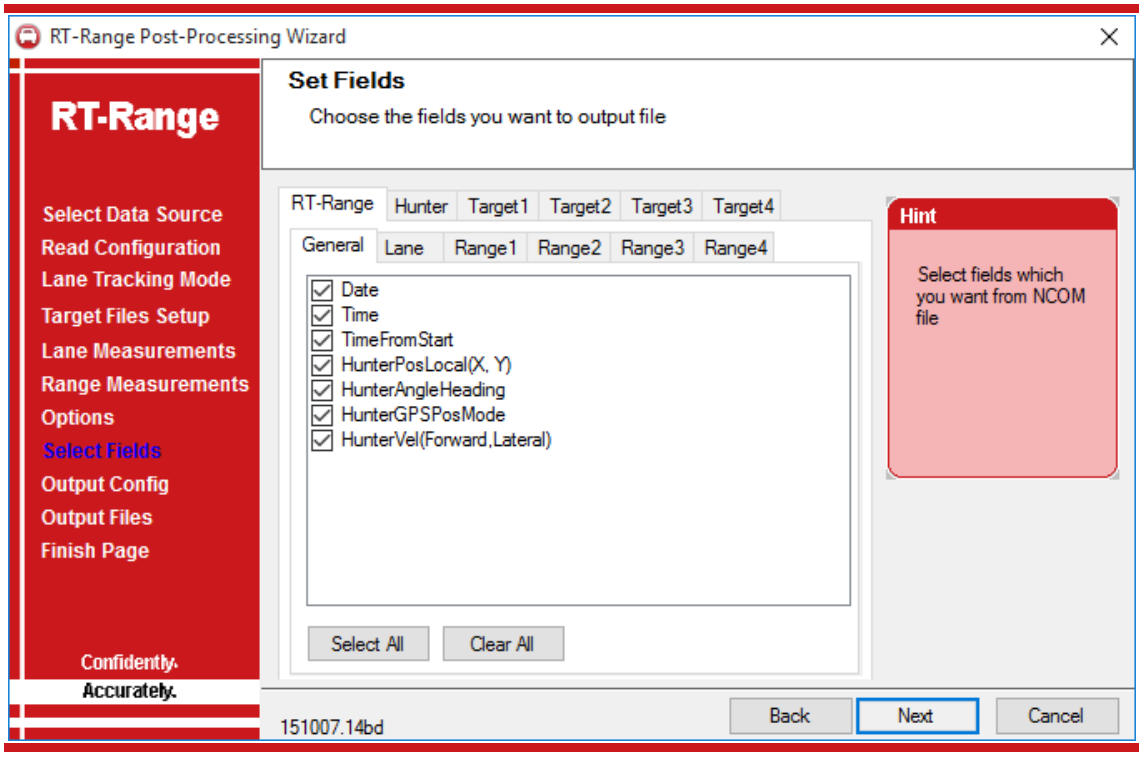
The Advanced option can be used to manually enter commands to configure RT-Range Post-Processing. Contact OxTS for further information.

Select Fields

The fields in the CSV file can be selected individually. If only some fields are needed then this can significantly reduce the size of the CSV file.

To select which fields should be output check or uncheck the fields, as shown in Figure 87.

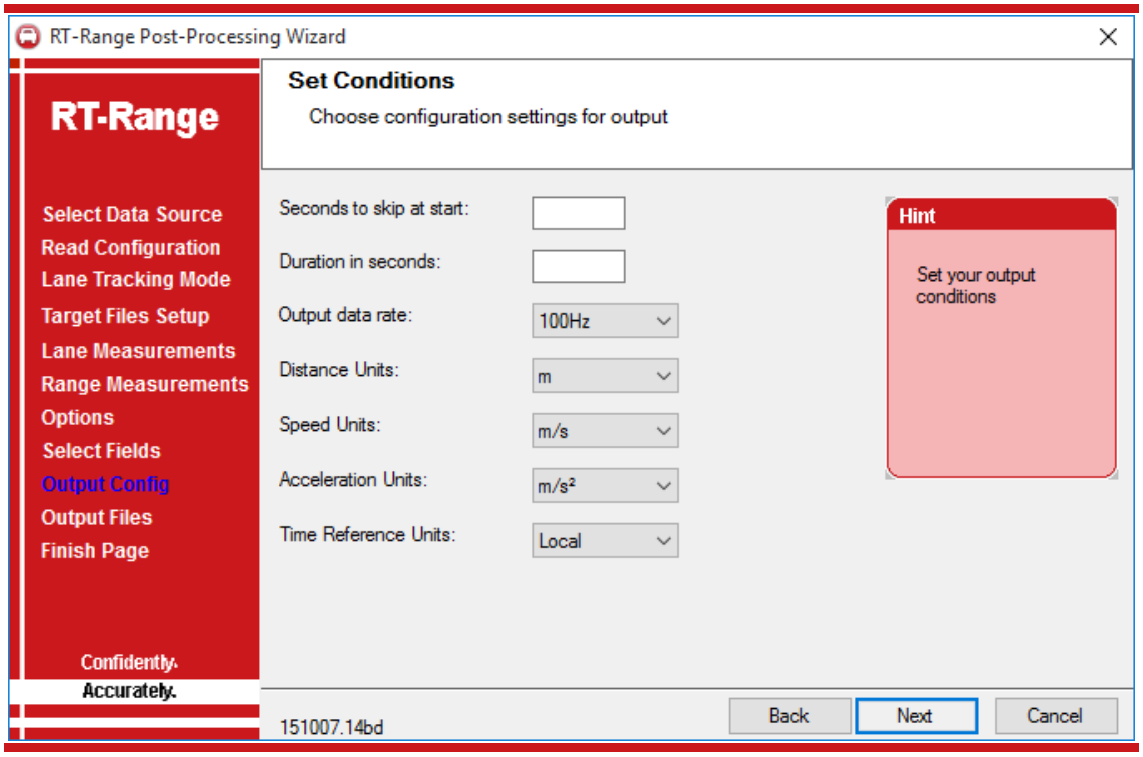
Figure 87. Select Fields in the RT-Range Post-Processing Wizard



Output Config

The Output Config page of the RT-Range Post-Process Wizard allows you to set the conditions for writing the output file and some of the units for the measurements. Figure 88 shows the Output Configuration page.

Figure 88. Output Config options



Seconds to skip at start. If a value is entered for this option then the output CSV file will have the first part of the data truncated from the file. This option helps split long CSV files in to smaller sections.

Duration in seconds. If a value is entered for this option then the CSV file will only include a short duration of data, rather than all the data until the end of the file.

Output data rate. This option can be used to decimate the output data to a lower data rate, e.g. 25 Hz.

Distance Units. The units metres, feet and yards can be selected for the distance based measurements (e.g. longitudinal range).

Speed Units. The units m/s, km/h, mph and knots can be selected for the velocity based measurements.

Acceleration Units. The acceleration can be measured in m/s² or in G. Note that G is an approximation since gravity is not constant across the earth.

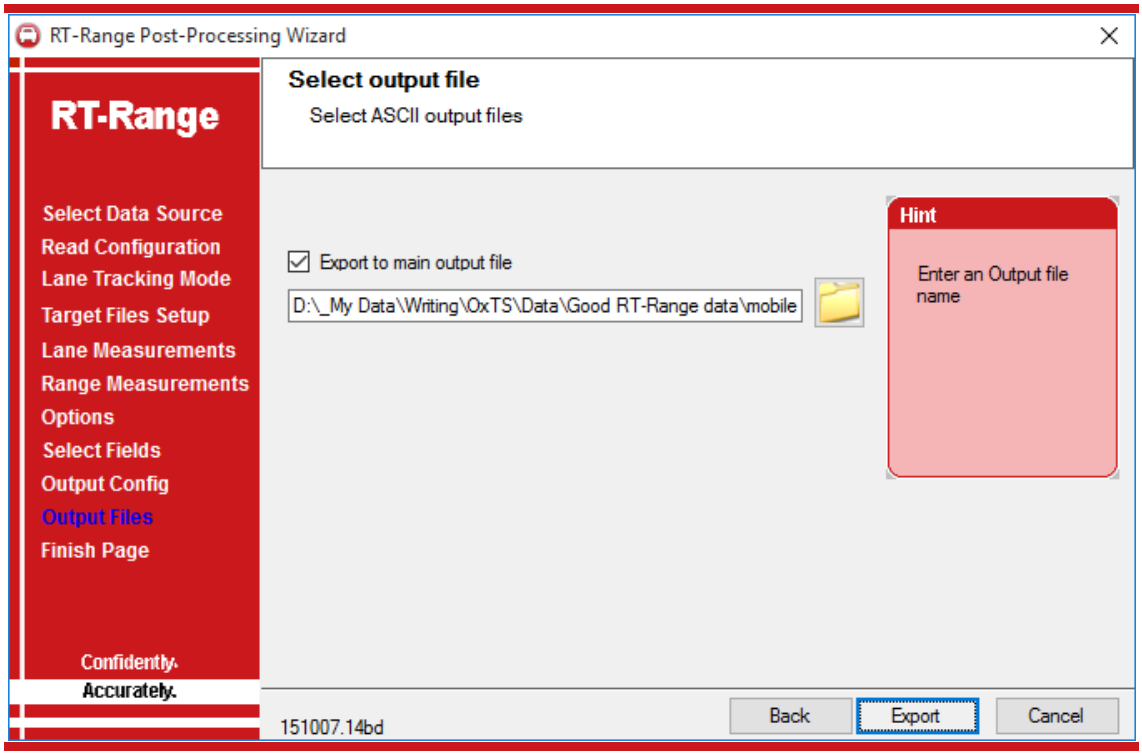
Time Reference Units. The time field of the CSV file can be changed so that it relates to different clock standards. The reference clock can either be the local time of the PC that is running the RT-Range Post-Processing wizard; UTC (GMT) time or GPS time.

The RT-Range measures in GPS time and UTC time by default. GPS and UTC time are currently 16 seconds different with 12:00:00 UTC time being 12:00:16 GPS time. The local time is computed by taking the time zone of the local computer and adding it to UTC time.

Output File

The output file needs to be chosen for the measurements. Figure 89 shows the Select Output File page of the RT-Range Post-Processing wizard.

Figure 89. Output Files page in the RT-Range Post-Processing Wizard



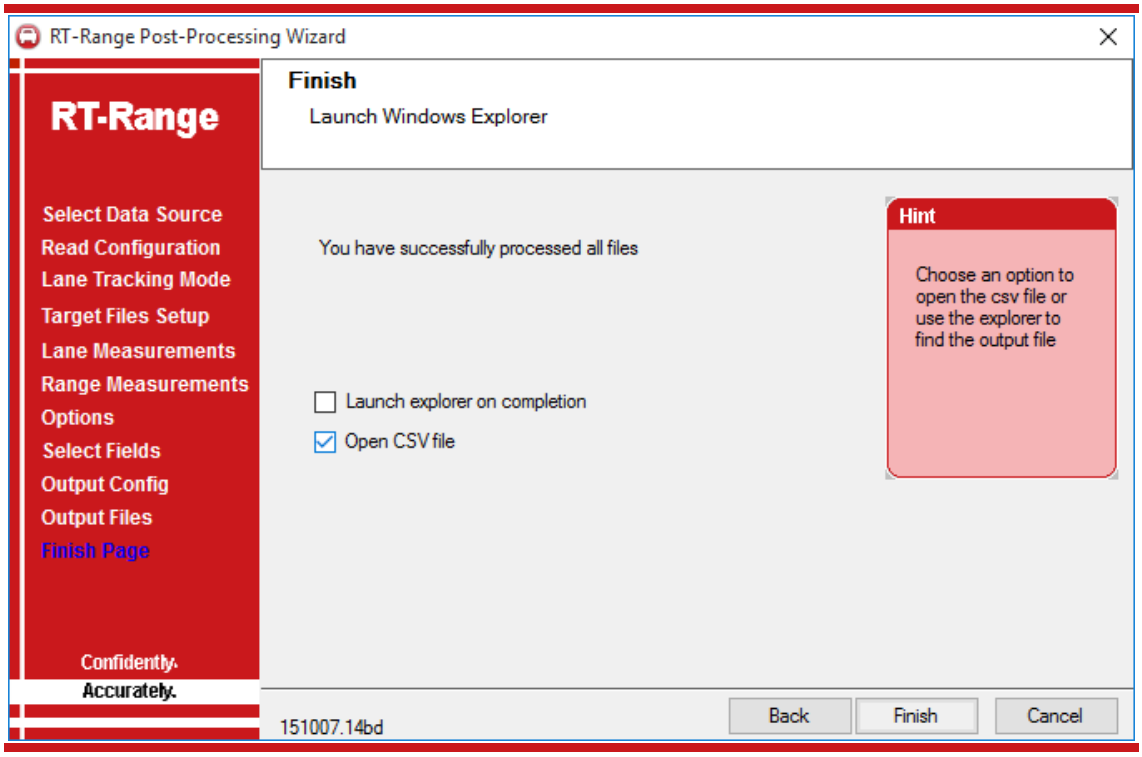
Check the *Export to main output file* checkbox and enter a filename for the output file.

When the *Export* button is clicked, the software will start processing the data. This may take some time for large files.

Finish Page

The Finish Page allows you to launch Explorer in the folder where the output file is created. Figure 90 shows the Finish Page of the RT-Range Post-Processing wizard.

Figure 90. Finish Page in the RT-Range Post-Processing Wizard



Outputs

The RT-Range outputs its data over Ethernet and over CAN. The Ethernet output is proprietary and is not described here; contact OxTS for more information. The CAN bus output is described in this section of the manual.

A CAN DBC file is generated by the RT-Range Configuration wizard in the CAN page. This DBC file reflects the configuration of the CAN bus that the user chooses.

The CAN bus output does not include a termination resistor. It is essential to include a 120 Ω resistor at each end of your CAN bus between CAN High and CAN Low. You should also connect the ground of your CAN bus.

Table 17 shows the pin connections for the Hunter CAN connector.

Table 17. Hunter CAN connector pin assignments

Signal	Pin
CAN -	2
CAN ground	3
CAN ground	6
CAN +	7

Other pins not connected internally.

CAN bus messages

Table 18 and Table 19 list the CAN messages that the RT-Range puts on the CAN bus and the identifiers that are used for these messages. These are the default identifiers, but they can be changed using the configuration software. The signals in each message are listed in the tables that follow.

Table 18. Default CAN bus messages for lane position measurements

Identifier (hex)	Data contents	See
7A0h	Map identifier and distance	Table 20
7A1h	Line on left of Point A	Table 21
7A2h	Line on right of Point A	Table 22
7A3h	Lines 1 to 4 to Point A	Table 23
7A4h	Lines 5 to 8 to Point A	Table 24
7A5h	Line to Point B	Table 25
7A6h	Line to Point C	Table 26
7A7h	Lines 1 to 4 to Point A velocity	Table 27
7A8h	Lines 5 to 8 to Point A velocity	Table 28
7A9h	Trajectory of A	Table 29
7AAh	Curvature of Lines 1 to 4	Table 30
7ABh	Curvature of Lines 5 to 8	Table 31
7ACh	Lines 1 to 4 to Point B	Table 32
7ADh	Lines 5 to 8 to Point B	Table 33
7AEh	Lines 1 to 4 to Point C	Table 34
7AFh	Lines 5 to 8 to Point C	Table 35
5A0h	Lane Point A lever arm	Table 36
5A1h	Lane Point B lever arm	Table 37
5A2h	Lane Point C lever arm	Table 38

Table 19. Default CAN bus messages for range measurements

Identifier (hex)				Data contents	Table
T1	T2	T3	T4		
7B0h	7C0h	7D0h	7E0h	Longitudinal measurements	Table 39
7B1h	7C1h	7D1h	7E1h	Lateral measurements	Table 40
7B2h	7C2h	7D2h	7E2h	Resultant measurements	Table 41
7B3h	7C3h	7D3h	7E3h	Position of hunter in local co-ordinates	Table 42
7B4h	7C4h	7D4h	7E4h	Position of target in local co-ordinates	Table 43
7B5h	7C5h	7D5h	7E5h	Status information	Table 44
7B6h	7C6h	7D6h	7E6h	Time gap	Table 45
7B7h	7C7h	7D7h	7E7h	Range in local co-ordinates	Table 46
7B8h	7C8h	7D8h	7E8h	Polygon measurements	Table 47
7B9h	7C9h	7D9h	7E9h	Feature point information	Table 48
5B0h	5C0h	5D0h	5E0h	Range offset	Table 49
5B1h	5C1h	5D1h	5E1h	Range fixed point latitude, longitude	Table 50
5B2h	5C2h	5D2h	5E2h	Range fixed point altitude, heading	Table 51
5B3h	5C3h	5D3h	5E3h	Range sensor lever arm	Table 52
5B4h	5C4h	5D4h	5E4h	Range bulls-eye lever arm	Table 53
5B5h	5C5h	5D5h	5E5h	Range target vehicle parameters	Table 54
5B6h	5C6h	5D6h	5E6h	Range accuracy	Table 55
5B7h	5C7h	5D7h	5E7h	Range feature point latitude, longitude	Table 56
5B8h	5C8h	5D8h	5E8h	Range feature point altitude, heading	Table 57

T1, T2, T3 and T4 are abbreviated from Target1, Target2, Target3 and Target4.

In addition to these messages, the RT-Range can output the navigation CAN messages from the target RTs. This allows all the RT measurements and the RT-Range measurements to be collected in one vehicle. See the RT manual for details of the target navigation CAN messages.

Heartbeat messages

Without a heartbeat message the RT-Range's CAN bus may not output anything until all the vehicles are configured, initialised and range measurements are being computed. This can make it difficult to check the operation in the garage before going out to test.

To avoid this, the RT-Range can output "heartbeat" CAN messages. These will be output even if range measurements and lane tracking measurements are not being computed and if no data is being received from the RTs. The messages are output approximately once per second.

The “heartbeat” messages are the Range Status messages (one for each target) and the Lane Map Status message. The Range Status heartbeat messages will only be output if the associated target is configured; if you have no targets configured then no Range Status heartbeat messages will be output. Similarly, if there is no map in the RT-Range then the Lane Map Status message will not be output. These messages will not be output if they are disabled in the CAN configuration. If no heartbeat messages are received, check that some operation of the RT-Range is configured and that the CAN bus is configured to output the heartbeat messages.

Table heading definitions

The fields in the tables have the following meanings.

Offset (bits). This is the offset into the message where the signal starts. To compute the offset in bytes divide the value by 8.

Length (bits). This is the length of the signal in bits. To compute the length of the signal in bytes, divide the value by 8.

Type. This specifies either an unsigned value (U) or a signed value (S).

Units. This is the units for the signal.

Factor. This is the factor that the integer unit should be multiplied by to get the signal into the units given in the table.

Offset. This is the value of the signal when the integer value in the CAN message is zero. It is zero for all the RT signals and can usually be discarded.

Signals

The following tables describe the signals in each of the messages.

Table 20. LaneMapStatus, map identifier and distance, identifier 7A0h (1952)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RefLineDistAlong: Distance travelled along Line 1.
32	8	U	–	–	–	MapNumber: Map number (FFh means invalid or no map)
40	8	U	–	–	–	Reserved
48	8	U	–	–	–	Reserved
56	8	U	–	–	–	Reserved

Note: If the distance is negative then the RT-Range is not computing the lane position. Lane position measurements will resume when the hunter vehicle drives through the start line. The negative values represent the distance to the start line.

Table 21. LeftLineLateral, line on left of Point A, identifier 7A1h (1953)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	LeftLinePosLateral: Lateral distance from Point A to Line
16	16	S	m/s	0.01	0	LeftLineVelLateral: Lateral velocity from Point A to Line
32	16	S	m/s²	0.01	0	LeftLineAccelLateral: Lateral acceleration from Point A to line
48	8	U	–	–	–	LeftLineNumber: Line number on left of Point A
56	8	U	–	–	–	Reserved

Note: When the RT-Range is not computing the lane position, the *line number on left of Point A* will be FFh and the measurements will be 8000h (full scale negative).

Table 22. RightLineLateral, line on right of Point A, identifier 7A2h (1954)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	RightLinePosLateral: Lateral distance from Point A to line
16	16	S	m/s	0.01	0	RightLineVelLateral: Lateral velocity from Point A to line
32	16	S	m/s²	0.01	0	RightLineAccelLateral: Lateral acceleration from Point A to line
48	8	U	–	–	–	RightLineNumber: Line number on right of Point A
56	8	U	–	–	–	Reserved

Note: When the RT-Range is not computing the lane position, the *line number on right of Point A* will be FFh and the measurements will be 8000h (full scale negative).

Table 23. Lines1To4PosLateralA, lines 1 to 4 to Point A, identifier 7A3h (1955)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	Line1PosLateralA: Distance from Point A to Line 1
16	16	S	m	0.001	0	Line2PosLateralA: Distance from Point A to Line 2
32	16	S	m	0.001	0	Line3PosLateralA: Distance from Point A to Line 3
48	16	S	m	0.001	0	Line4PosLateralA: Distance from Point A to Line 4

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 24. Lines5To8PosLateralA, lines 5 to 8 to Point A, identifier 7A4h (1956)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	Line5PosLateralA: Distance from Point A to Line 5
16	16	S	m	0.001	0	Line6PosLateralA: Distance from Point A to Line 6
32	16	S	m	0.001	0	Line7PosLateralA: Distance from Point A to Line 7
48	16	S	m	0.001	0	Line8PosLateralA: Distance from Point A to Line 8

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 25. LinesFromB, line to Point B, identifier 7A5h (1957)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	LeftFromBPosLateral: Distance from Point B to line on left of A
16	8	U	–	–	–	LeftOfBNumber: Line number on the left of B
24	8	U	–	–	–	RightOfBNumber: Line number on the right of B
32	16	S	1/m	0.0001	0	CurvatureOfB: Instantaneous curvature of Point B

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative). When there is no line number on the left or right of point B then the field will be FFh.

Table 26. LinesFromC, line to Point C, identifier 7A6h (1958)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	RightFromCPosLateral: Distance from Point C to line on right of A
16	8	U	–	–	–	LeftOfCNumber: Line number on the left of C
24	8	U	–	–	–	RightOfCNumber: Line number on the right of C
32	16	S	1/m	0.0001	0	CurvatureOfC: Instantaneous curvature of Point C

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative). When there is no line number on the left or right of point C then the field will be FFh.

Table 27. Lines1To4VelLateralA, lines 1 to 4 to Point A velocity, identifier 7A7h (1959)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m/s	0.01	0	Line1VelLateralA: Velocity from Point A to Line 1
16	16	S	m/s	0.01	0	Line2VelLateralA: Velocity from Point A to Line 2
32	16	S	m/s	0.01	0	Line3VelLateralA: Velocity from Point A to Line 3
48	16	S	m/s	0.01	0	Line4VelLateralA: Velocity from Point A to Line 4

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 28. Lines5To8VelLateralA, lines 5 to 8 to Point A velocity, identifier 7A8h (1960)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m/s	0.01	0	Line5VelLateralA: Velocity from Point A to Line 5
16	16	S	m/s	0.01	0	Line6VelLateralA: Velocity from Point A to Line 6
32	16	S	m/s	0.01	0	Line7VelLateralA: Velocity from Point A to Line 7
48	16	S	m/s	0.01	0	Line8VelLateralA: Velocity from Point A to Line 8

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 29. TrajectoryOfA, heading of A relative to surrounding lines and curvature of A, Identifiers 7A9h (1961)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	degrees	0.01	0	LeftLineHeadingOfA: Heading with respect to the line to the left of Point A
16	16	S	degrees	0.01	0	RightLineHeadingOfA: Heading with respect to the line to the right of Point A
32	16	S	1/m	0.0001	0	CurvatureOfA: Instantaneous curvature of Point A

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 30. Lines1To4Curvature, curvature of Lines 1 to 4, Identifier 7AAh (1962)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	1/m	0.0001	0	Line1Curvature: Curvature of Line 1
16	16	S	1/m	0.0001	0	Line2Curvature: Curvature of Line 2
32	16	S	1/m	0.0001	0	Line3Curvature: Curvature of Line 3
48	16	S	1/m	0.0001	0	Line4Curvature: Curvature of Line 4

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 31. Lines5To8Curvature, curvature of lines 5 to 8, identifier 7ABh (1963)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	1/m	0.0001	0	Line5Curvature: Curvature of Line 5
16	16	S	1/m	0.0001	0	Line6Curvature: Curvature of Line 6
32	16	S	1/m	0.0001	0	Line7Curvature: Curvature of Line 7
48	16	S	1/m	0.0001	0	Line8Curvature: Curvature of Line 8

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 32. Lines1To4PosLateralB, lines 1 to 4 to Point B, identifier 7ACh (1964)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	Line1PosLateralB: Distance from Point B to Line 1
16	16	S	m	0.001	0	Line2PosLateralB: Distance from Point B to Line 2
32	16	S	m	0.001	0	Line3PosLateralB: Distance from Point B to Line 3
48	16	S	m	0.001	0	Line4PosLateralB: Distance from Point B to Line 4

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 33. Lines5To8PosLateralB, lines 5 to 8 to Point B, identifier 7ADh (1965)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	Line5PosLateralB: Distance from Point B to Line 5
16	16	S	m	0.001	0	Line6PosLateralB: Distance from Point B to Line 6
32	16	S	m	0.001	0	Line7PosLateralB: Distance from Point B to Line 7
48	16	S	m	0.001	0	Line8PosLateralB: Distance from Point B to Line 8

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 34. Lines1To4PosLateralC, lines 1 to 4 to Point C, identifier 7AEh (1966)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	Line1PosLateralC: Distance from Point C to Line 1
16	16	S	m	0.001	0	Line2PosLateralC: Distance from Point C to Line 2
32	16	S	m	0.001	0	Line3PosLateralC: Distance from Point C to Line 3
48	16	S	m	0.001	0	Line4PosLateralC: Distance from Point C to Line 4

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 35. Lines5To8PosLateralC, lines 5 to 8 to Point C, identifier 7AFh (1967)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m	0.001	0	Line5PosLateralC: Distance from Point C to Line 5
16	16	S	m	0.001	0	Line6PosLateralC: Distance from Point C to Line 6
32	16	S	m	0.001	0	Line7PosLateralC: Distance from Point C to Line 7
48	16	S	m	0.001	0	Line8PosLateralC: Distance from Point C to Line 8

Note: When the RT-Range is not computing the lane position then the measurements will be 8000h (full scale negative).

Table 36. LanePointALeverArm: lever arm from the RT to the lane measurement Point A, identifier 5A0h (1440)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	I	m	0.001	0	LanePointALeverArmX: Lever arm from the RT to lane measurement point A in the *x* direction.
16	16	I	m	0.001	0	LanePointALeverArmY: Lever arm from the RT to lane measurement point A in the *y* direction.
32	16	I	m	0.001	0	LanePointALeverArmZ: Lever arm from the RT to lane measurement point A in the *z* direction.

Table 37. LanePointBLeverArm: Lever arm from the RT to the lane measurement Point B, identifier 5A1h (1441)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	I	m	0.001	0	LanePointBLeverArmX: Lever arm from the RT to lane measurement point B in the *x* direction.
16	16	I	m	0.001	0	LanePointBLeverArmY: Lever arm from the RT to lane measurement point B in the *y* direction.
32	16	I	m	0.001	0	LanePointBLeverArmZ: Lever arm from the RT to lane measurement point B in the *z* direction.

Table 38. LanePointCLeverArm: Lever arm from the RT to the lane measurement Point C, identifier 5A2h (1442)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	I	m	0.001	0	LanePointCLeverArmX: Lever arm from the RT to lane measurement point C in the *x* direction.
16	16	I	m	0.001	0	LanePointCLeverArmY: Lever arm from the RT to lane measurement point C in the *y* direction.
32	16	I	m	0.001	0	LanePointCLeverArmZ: Lever arm from the RT to lane measurement point C in the *z* direction.

Table 39. RangeForward, Longitudinal measurements, identifiers 7B0h (1968), 7C0h (1984), 7D0h (2000), 7E0h (2016)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RangePosForward: Longitudinal range
32	16	S	m/s	0.01	0	RangeVelForward: Longitudinal velocity
48	16	S	s	0.001	0	RangeTimeToCollisionForward: Longitudinal time to collision, computed using range and velocity but not acceleration

Table 40. RangeLateral, Lateral measurements, identifiers 7B1h (1969), 7C1h (1985), 7D1h(2001), 7E1h (2017)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RangePosLateral: Lateral range
32	16	S	m/s	0.01	0	RangeVelLateral: Lateral velocity
48	16	S	s	0.001	0	RangeTimeToCollisionLateral: Lateral time to collision, computed using range and velocity but not acceleration

Table 41. RangeResultant, Resultant measurements, identifiers 7B2h (1970), 7C2h (1986), 7D2h (2002), 7E2h (2018)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RangePosRes: Resultant range
32	16	S	m/s	0.01	0	RangeVelRes: Resultant velocity
48	16	S	degrees	0.01	0	RangeAngleHeading: Angle to target in view of the hunter

The resultant velocity is the rate of change of the resultant range and not the modulus of the longitudinal/lateral velocity vector.

Table 42. RangeHunterPosLocal, Position of hunter in local co-ordinates, identifiers 7B3h (1971), 7C3h (1987), 7D3h (2003), 7E3h (2019)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RangeHunterPosLocalX: *x* distance from origin
32	32	S	m	0.001	0	RangeHunterPosLocalY: *y* distance from origin

Note: The convention used for the local co-ordinates is with the *z*-axis up.

Table 43. RangeTargetPosLocal, Position of target in local co-ordinates, identifiers 7B4h (1972), 7C4h (1988), 7D4h (2004), 7E4h (2020)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RangeTargetPosLocalX: *x* Distance from origin
32	32	S	m	0.001	0	RangeTargetPosLocalY: y Distance from origin

Note: these values are predicted to real-time if the communication link(s) has more delay than the range delay field. The convention used for the local co-ordinates is with the z-axis up.

Table 44. RangeStatus: Status information for range measurements, identifiers 7B5h (1973), 7C5h (1989), 7D5h (2005), 7E5h (2021)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	8	U	–	–	–	RangeHunderGpsPosMode: Hunter GPS position mode
8	8	U	–	–	–	RangeTargetGpsPosMode: Target GPS position mode
16	16	U	s	0.001	0	RangeRangeTargetLatency: Prediction used for target measurements
32	16	U	s	0.001	0	RangeRangeOutputLatency: Output latency (range delay)
48	8	U	–	–	–	RangeStatusByte
56	8	U	–	–	–	RangeRefPlane

Note that this is a “heartbeat” message and, if configured, it will be output periodically on the CAN bus even if no RTs are connected to the RT-Range. It is useful for checking that the RT-Range CAN bus is working.

Table 45. RangeTimeGap: Time gap between target and hunter, identifiers 7B6h (1974), 7C6h (1990), 7D6h (2006), 7E6h (2022)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	s	0.001	0	RangeTimeGap: Time gap between target and hunter vehicles. This is the longitudinal range divided by the speed of the hunter vehicle.
16	16	S	s	0.001	0	TimeToCollisionForwardWithAccel: This is the time to collision in the forward direction computed using range, velocity and acceleration.

Note: Time to collision with acceleration is not available for fixed point or static targets. A minimum acceleration of 0.05 m/s^2 is required. By default unfiltered acceleration is used for this calculation. Filters can be applied before the calculation using Advanced commands (see page 94).

Table 46. RangeLocal: Difference in position of hunter and target in local co-ordinates, identifiers 7B7h (1975), 7C7h (1991), 7D7h (2007), 7E7h (2023)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	RangeLocalDeltaX: *x* Distance from hunter
32	32	S	m	0.001	0	RangeLocalDeltaY: *y* Distance from hunter

Note: The convention used for the local co-ordinates is with the *z*-axis up.

Table 47. RangePolygon, Polygon measurements, identifiers 7B8h (1976), 7C8h (1992), 7D8h, (2008), 7E8h (2024)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	8	U	–	–	0	RangePolygonVisible: Percentage of the target that is not hidden behind other targets
8	8	U	–	–	0	RangePolygonInside: Check whether the hunter is inside the target polygon. If this is true then the answers may be incorrect (and the vehicles may have crashed). Please note that this field is not available in RCOM data.
16	8	U	–	–	0	RangePolygonLeftPoint: Polygon point number to the left of the closest range to the polygon
24	8	U	–	–	0	RangePolygonRightPoint: Polygon point number to the right of the closest range to the polygon

Table 48. RangeFeatInfo: Range feature point information, identifiers 7B9h (1977), 7C9h (1993), 7D9h (2009), 7E9h (2025)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	U	-	-	0	RangeFeatId: Feature point ID. The ID of the feature being tracked is only valid when it is not one of 0000h (disabled). FFFEh (unknown or no feature selected) and FFFFh (invalid).
16	8	U	-	-	0	RangeFeatType: Feature point type. The type of the feature being tracked is only valid when it is not one of 00h (disabled). FEh (unknown or no feature selected) and FFh (invalid).

Table 49. RangeOffset: Offsets to the range measurements, identifiers 5B0h (1456), 5C0h (1472), 5D0h (1488), 5E0h (1504)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	I	m	0.001	0	RangeOffsetForward: Value added to the longitudinal range before it is output.
16	16	I	m	0.001	0	RangeOffsetLateral: Value added to the lateral range before it is output.

Note: The range offsets are used to make minor adjustments to the range measurements.

Table 50. RangeFixedPointLL: Latitude and longitude of fixed points, identifiers 5B1h (1457), 5C1h (1473), 5D1h (1489), 5E1h (1505)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	I	degrees	1e-7	0	RangeFixedPointLat: Latitude of the fixed point.
32	32	I	degrees	1e-7	0	RangeFixedPointLon: Longitude of the fixed point.

Note: These outputs have a resolution of about 1 cm, which may not be precise enough for all applications. Internally the RT-Range has more resolution.

Table 51. RangeFixedPointHH: Altitude and heading of fixed points, identifiers 5B2h (1458), 5C2h (1474), 5D2h (1490), 5E2h (1506)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	I	m	0.001	0	RangeFixedPointAlt: Altitude of the fixed point.
32	16	U	degrees	0.01	0	RangeFixedPointHea: Heading of the fixed point.

Table 52. RangeSensorLeverArm: Lever arm from the RT to the sensor point, identifiers 5B3h (1459), 5C3h (1475), 5D3h (1491), 5E3h (1507)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	I	m	0.001	0	RangeSensorLeverArmX: Lever arm from the RT to the sensor point in the *x* direction.
16	16	I	m	0.001	0	RangeSensorLeverArmY: Lever arm from the RT to the sensor point in the *y* direction.
32	16	I	m	0.001	0	RangeSensorLeverArmZ: Lever arm from the RT to the sensor point in the *z* direction.

Table 53. RangeBullsEyeLeverArm: Lever arm from the RT to the bulls-eye point, identifiers 5B4h (1460), 5C4h (1476), 5D4h (1492), 5E4h (1508)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	I	m	0.001	0	RangeBullsEyeLeverArmX: Lever arm from the RT to the bulls-eye point in the *x* direction.
16	16	I	m	0.001	0	RangeBullsEyeLeverArmY: Lever arm from the RT to the bulls-eye point in the *y* direction.
32	16	I	m	0.001	0	RangeBullsEyeLeverArmZ: Lever arm from the RT to the bulls-eye point in the *z* direction.

Table 54. RangeVehicle: User parameters about the target vehicle, identifiers 5B5h (1461), 5C5h (1477), 5D5h (1493), 5E5h (1509)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	U	m	0.001	0	RangeTargetVehicleLength: User entered vehicle length.
16	16	U	m	0.001	0	RangeTargetVehicleWidth: User entered vehicle width.
32	16	U	–	–	–	RangeTargetPolygonNumber: User entered polygon number.

Table 55. RangePosStdev: Standard deviation of the range measurements, identifiers 5B6h (1462), 5C6h (1478), 5D6h (1494), 5E6h (1510)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	U	m	0.001	0	RangePosForwardStdev: Standard deviation of the range in the longitudinal direction.
16	16	U	m	0.001	0	RangePosLateralStdev: Standard deviation of the range in the lateral direction.
32	16	U	m	0.001	0	RangePosDownStdev: Standard deviation of the range in the vertical direction.
48	16	U	m	0.001	0	RangePosMagStdev: This is the standard deviation of the resultant range measurement. It may be less than the other three accuracies, particularly when the target is offset by a 45 degree angle.

Note: these accuracy estimates use the accuracy estimates of the RT and take into account the position and orientation effects.

Table 56. RangeFeatPointLL: Latitude and longitude of feature points, identifiers 5B7h (1463), 5C7h (1479), 5D7h (1495), 5E7h (1511)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	I	degrees	1e-7	0	RangeFeatPointLat: Latitude of the feature point
32	32	I	degrees	1e-7	0	RangeFeatPointLon: Longitude of the feature point

Note: These outputs have a resolution of about 1 cm, which may not be precise enough for all applications. Internally the RT-Range has more resolution.

Table 57. RangeFeatPointHH: Altitude and heading of feature points, identifiers 5B8h (1464), 5C8h (1480), 5D8h (1496), 5E8h (1512)

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	I	m	0.001	0	RangeFeatPointAlt: Altitude of the feature point.
32	16	U	degrees	0.01	0	RangeFeatPointHea: Heading of the feature point.

Calculation details

Although in an overview the problem of computing the range or tracking the line seems trivial, there are some aspects of the physics that require some explanation. There are different interpretations on range (2D or 3D for example). This can lead to differences in the measurements between the RT-Range and the outputs of other sensors. These are not necessarily errors, they are differences in the calculations. Some of the differences that may be experienced are explained in this section.

Range measurement effects

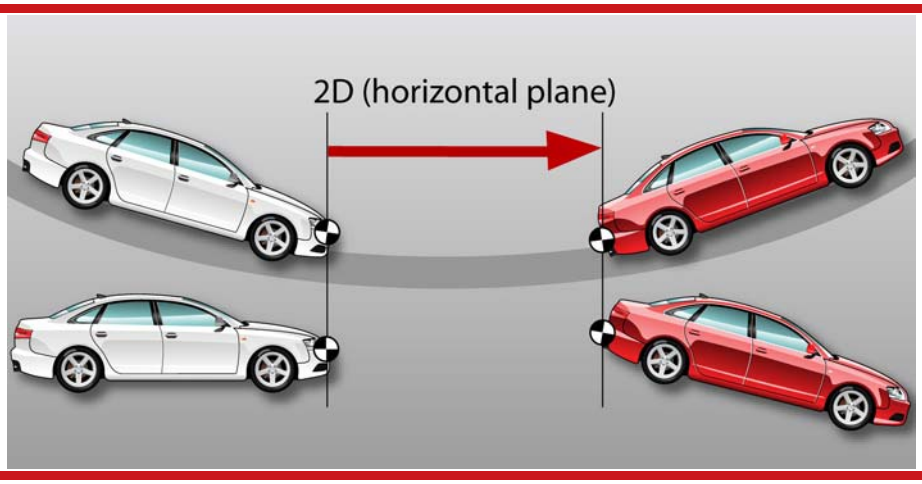
There are two main effects on the data in the range measurements. These are due to errors in heading and due to viewing the target vehicle from the co-ordinate frame of the hunter vehicle. There is also the effect of the communication link delay and the transient effect this has on the measurements.

2D and 3D measurement planes

By default the RT-Range computes the range in the horizontal plane. This is the distance between the vehicles viewed from above with no altitude or orientation effects. It is also possible to configure the RT-Range to output the distance projected into a measurement plane that is attached to the hunter's orientation.

Figure 91 shows the horizontal measurement plane solution. The range between either of the hunter vehicles (white) to either target vehicle (red) will be the same, regardless of orientation of either vehicle or their difference in altitude.

Figure 91. Horizontal (2D) measurement plane calculation

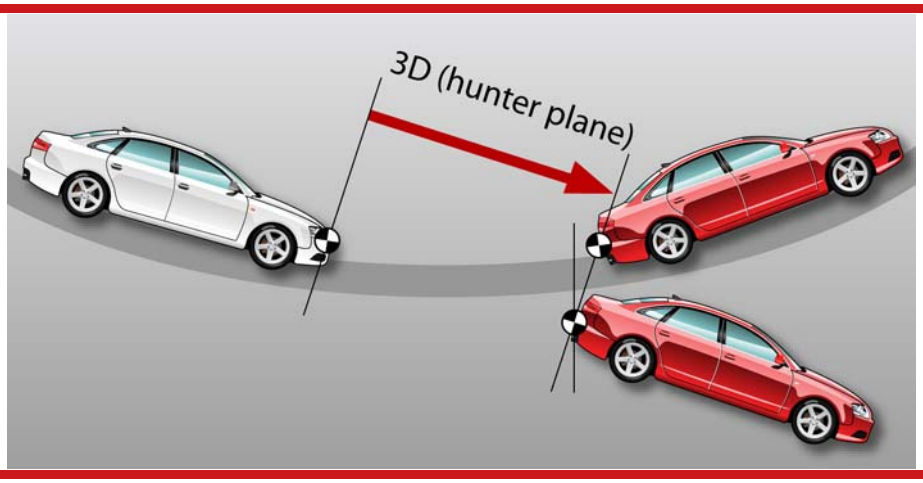


In the 2D horizontal plane mode a full 3D calculation is still used to compute the sensor point and the bulls-eye point from the position of the RT; the orientation of the vehicle does affect the position of the sensor and bulls-eye points.

When the measurement plane is attached to the hunter vehicle then the range is computed along a measurement plane that is angled with the hunter vehicle. Figure 92 shows the hunter measurement plane solution. The two target vehicles (red) have the same forward (longitudinal) range when using the hunter measurement plane; in the horizontal measurement plane the top target vehicle would have a longer forward range.

In mathematical terms the 3D range vector from the sensor point on the hunter to the bulls-eye point on the target (or closest part of the polygon) is computed. Then this 3D vector is projected in to the forward and lateral (right) directions of the hunter vehicle. The hunter z-axis information is not output.

Figure 92. Hunter (3D) measurement plane calculation



When using the hunter measurement plane it is important to align the pitch measurements of the RT in the hunter with the pitch measurement of the sensor. The Enginuity software that comes with the RT has tools for adjusting the pitch measurements of the RT.

It should be noted that the difference in range between the horizontal measurement plane and the hunter measurement plane is very small except on very steep slopes.

Polygons

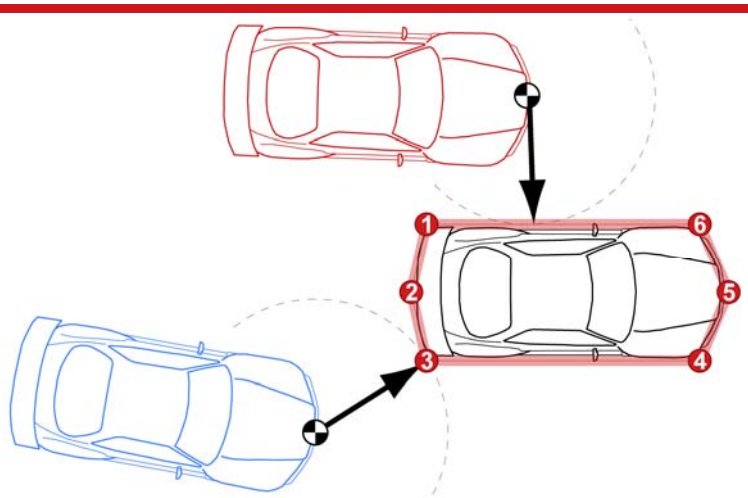
Targets and fixed points in the RT-Range can be represented as polygons. The RT-Range will then compute the range from the hunter to the closest part of the polygon. Polygons are planar (or flat) and are orientated by the heading, pitch and roll

of the target vehicle. For a fixed point the heading of the fixed point needs to be entered and the pitch and roll are zero.

There are some restrictions on the polygons that can be used in the RT-Range. The polygons cannot have intersecting or overlapping lines. They need to have a minimum of 3 points and a maximum of 24 points. All the points are assumed to lie in the same plane. Concave sets of points should be avoided. The results may not be correct when the sensor point of the hunter is inside the polygon. These restrictions are not normally a problem when using a polygon to represent the outline of a vehicle.

The polygon algorithm will either track the closest point or the closest edge, depending on which one is closer. Figure 93 shows the red hunter tracking the edge of the target, between points 1 and 6 and the blue hunter tracking point 3.

Figure 93. Polygon point or edge tracking



For the red hunter, the Range Polygon output message will identify point 1 as the point on the right and point 6 as the point on the left. For the blue hunter the Range Polygon output message will identify point 3 for both the left and the right points.

Note that the points are ordered in Figure 93. The points must be entered into the software ordered either clockwise or anti-clockwise. The software will use lines to connect consecutive points and the lines cannot intersect. The software will not work out the bounding box around a randomly ordered set of points. The final point will connect to point 1 (i.e. point 6 in Figure 93).

Range velocity with polygons

The range velocity is ambiguous when the closest edge is being tracked. The RT-Range computes the difference between the instantaneous velocity of the sensor point compared to the edge of the polygon.

For example, in Figure 93 the red hunter is tracking the edge between points 1 and 6. Assuming that the hunter is overtaking the target then the range velocity forward (longitudinal) will be approximately the difference in speed between the hunter and the target vehicles. Another interpretation would be that the range velocity forward would be zero since the intersection point is also moving, which is not what the RT-Range outputs. This interpretation avoids large jumps in range velocity lateral when the blue hunter turns and the point tracked jumps quickly (possibly immediately) from point 2 to point 3.

The velocity implementation in the RT-Range may be different to the velocity used by other sensor systems.

Errors in heading

At large distances the heading accuracy of the RT has a large effect on the lateral range measurement. Although the RT3002 system can measure heading accurate to as low as 0.1 degrees, this can cause the lateral range measurement to have significant errors in it.

Table 58 shows the error in the lateral range for a 0.1 degree error for different distances.

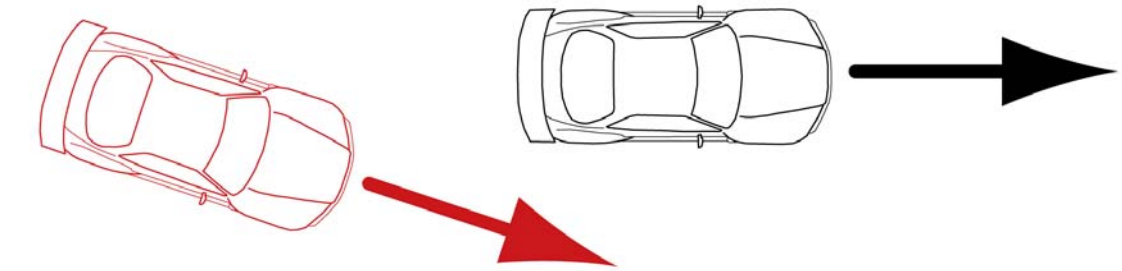
Table 58. Lateral error for different ranges for 0.1 deg heading error

Range to Target	Lateral Range Error
5 m	0.9 cm
10 m	1.7 cm
20 m	3.5 cm
50 m	8.7 cm
100 m	17 cm

Lateral velocity effects

Consider the lateral velocities of the hunter and target vehicles in Figure 94; they are both zero. Yet the lateral range velocity is not zero.

Figure 94. Lateral velocity of the target compared to the hunter



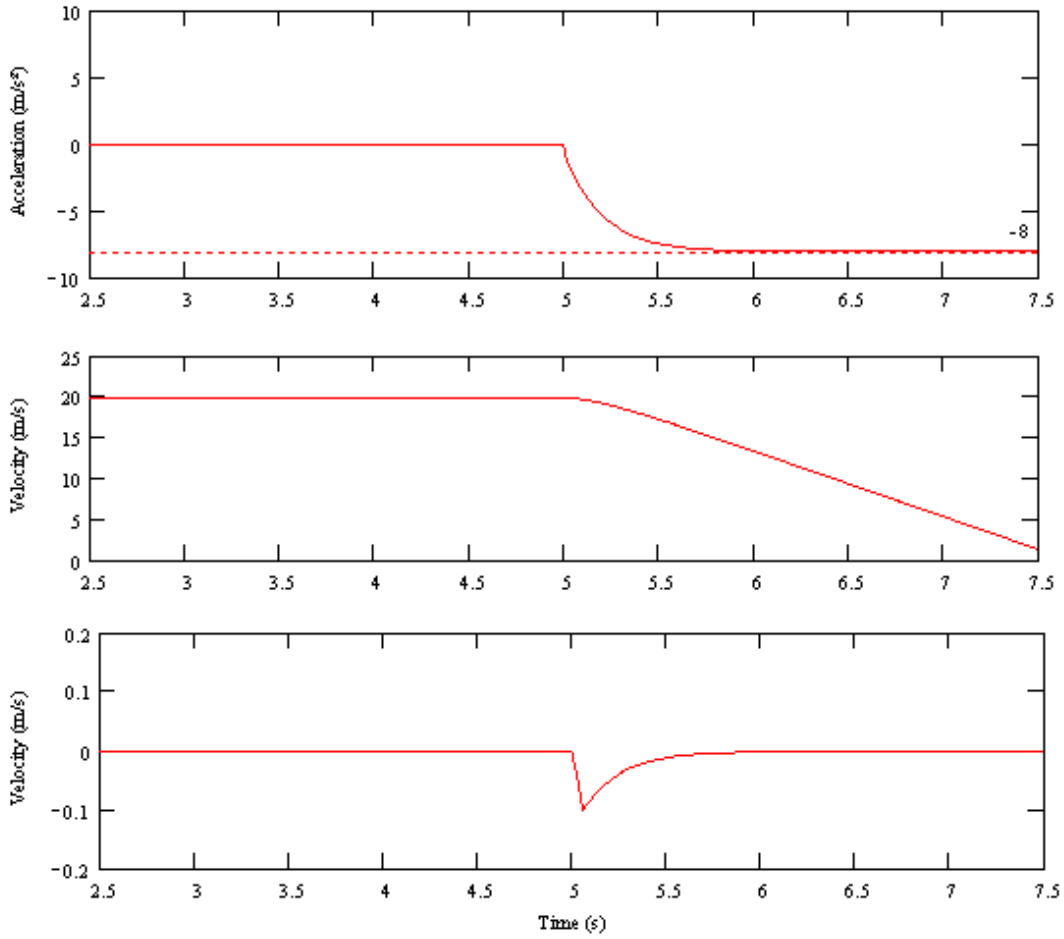
This effect is also seen if you have a stationary hunter vehicle, a stationary target (or fixed point) and somehow rotate the hunter vehicle on the spot. The lateral range velocity will not be zero, even though everything is stationary.

Transient errors due to communication link delay

The RT-Range uses a constant acceleration model for predicting the position and velocity of the target vehicle. This prediction is to overcome the delay in the communication link (either Wireless LAN or radio modem or both).

The effect on position for this type of transient is small (less than 1 cm). The effect on the velocity is higher. Figure 95 shows the acceleration curve, velocity curve and velocity error for a 0.8 *g* sudden acceleration; it assumes a communication link delay of 70 ms, which is about the peak expected from the Wireless LAN when the vehicles are close.

Figure 95. Example transient error for 0.8 *g* acceleration on target vehicle



It can be seen from the graph that the effect on the velocity measurement for this transient is large (0.1 m/s is over 3 times larger than the RMS specification). The error duration is short and the error is not present for the whole of the test, just during the period when the acceleration changes.

This error can be removed by increasing the output latency or by post-processing the data.

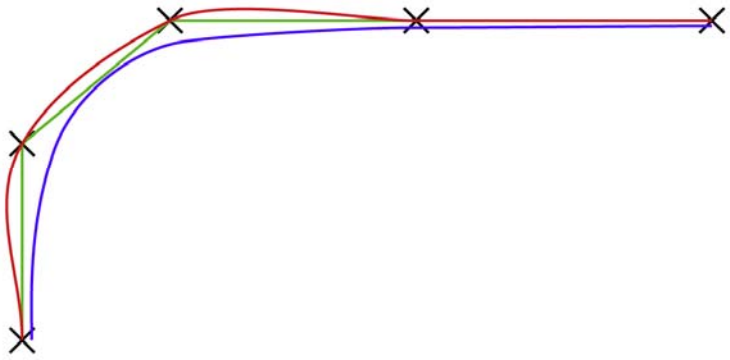
Lane position measurement effects

The problem of surveying lane markings, constructing a map and computing the outputs is not trivial when accuracies in the centimetre region are required. It is very unlikely that the person who painted the road managed to paint it accurately, especially on bends. But, small changes in curvature of the line have huge effects on the acceleration measurements.

There is also the problem of constructing a smooth line for the RT-Range to follow. It is possible to use splines, fit curves or to simply use straight segments. All solutions have their associated problems.

Initially splines are an obvious choice but there are problems in the detail. Figure 96 shows five points with three different fitting techniques.

Figure 96. Fitting between the points on the lines



Spline fitting exactly on all the points. A spline that fits exactly on all the points is drawn in red in Figure 96. This type of spline is very accurate at the surveyed points, but it is not clear what the error will be between the points. It will tend to overshoot after curves.

Spline smoothing all the points. A spline that smoothes the points does not actually pass through any of the points that are surveyed. This type of spline cuts corners.

Straight line fit between all the points. Fitting a straight line between the surveyed points gives accurate measurements at the points and does not overshoot in between the points. However, the straight line has larger errors on curves or circles. It also has other associated problems, such as discontinuities in distance, abrupt changes in curvature (that affect acceleration) etc.

The straight line fit is, however, the easiest solution to the problem and the one that is least likely to give unexplainable results. It is the solution that has been used in the RT-Range. Ultimately it probably offers the best accuracy if the survey is conducted correctly.

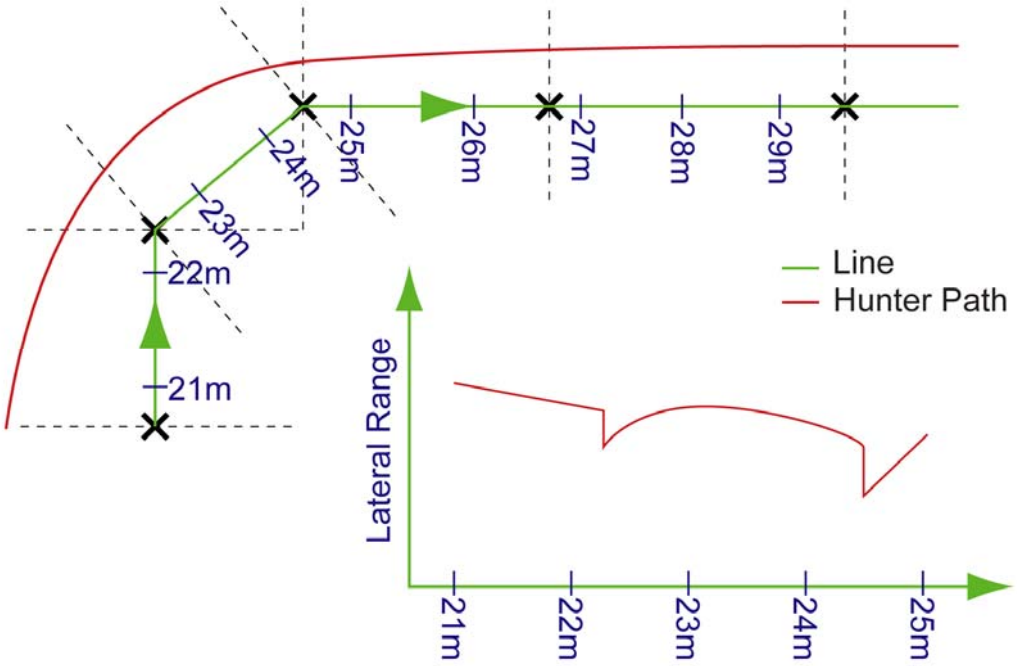
The errors shown here in the drawing may look small considering how tight the curve is. But, when the points are surveyed at 1 m spacing, typical for large road surveys, then it is easy to introduce errors of 1 cm or more in the curve fitting. This cannot

easily be seen on paper but it is significant compared to the measurement accuracy of the RT-Range.

Discontinuous distance

Consider the Line in Figure 97. In this example the vehicle is driving on the outside of the bend. There are sections that the vehicle has to travel, but there is no distance moved along the bend. This leads to jumps in the distance output.

Figure 97. Discontinuous distance at the points



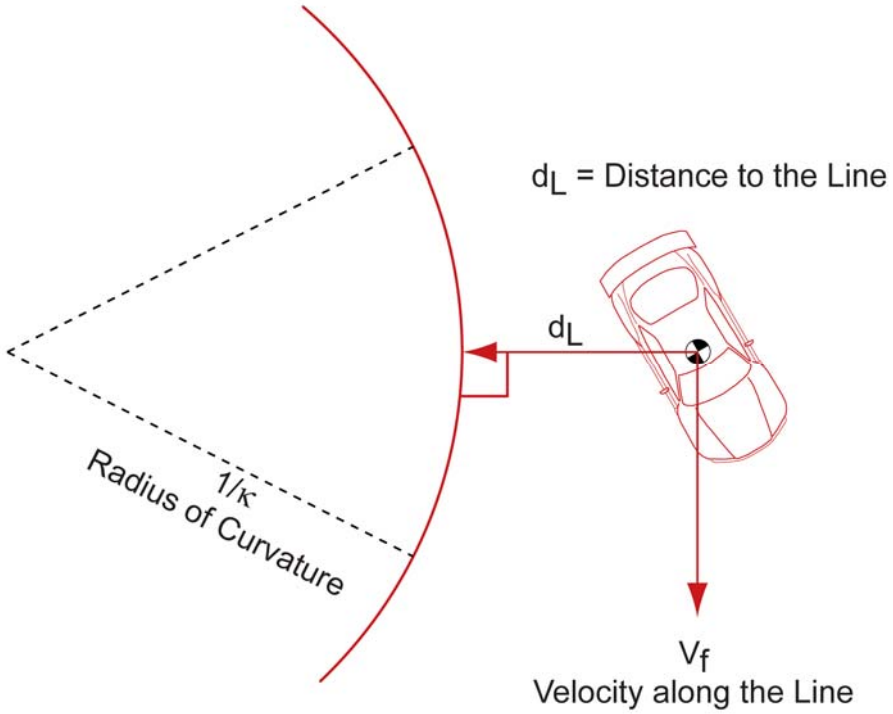
In normal circumstances this is not a problem. Distance is normally only used as an indication of track position and it is not normally critical to the plotting of the graph. Also, the jumps are much smaller than the ones shown here. The lateral distance from the line is also discontinuous for the same reason.

It should be noted that the jumps increase as you get tighter bends and as you get further away from the reference line (Line 1).

Co-ordinates for measurements with respect to the Lines

There are two co-ordinate frames that are possible for the distance to the line measurement. One is perpendicular to the hunter vehicle and the other is perpendicular to the line. The RT-Range measures the distance that is perpendicular to the line, as shown in Figure 98.

Figure 98. Co-ordinate system for the line measurements



Acceleration on curves

There are two terms for the acceleration of the hunter vehicle with respect to the line. There is the acceleration of the hunter vehicle plus the curvature of the line. The curvature of the line accounts for the circumstance where the hunter vehicle travels straight with no acceleration and the line curves towards or away from the hunter vehicle.

In Figure 98 the hunter vehicle could be travelling in a straight line, however the line is curved and so there is some acceleration of the hunter vehicle away from the line. The RT-Range computes the acceleration relative to the line as:

$$-a_L + \frac{\kappa}{1+\kappa \cdot d_L} \cdot V_f^2$$

where a_L is the acceleration of the vehicle in the co-ordinate frame of the line; κ is the instantaneous curvature of the line; d_L is the distance to the line and V_f is the velocity of the hunter vehicle along the line.

Using the formula above makes sure that, if the hunter vehicle is travelling on a circle that has the same centre as the line then there will be no acceleration relative to the line.

Effect of the line survey on the accuracy

There are several conflicting problems facing the line survey process. For accurate tracking of the lane markings the points should be as close together as possible; but making the points closer makes the curvature noisier.

Figure 99. Error using straight lines to approximate curves

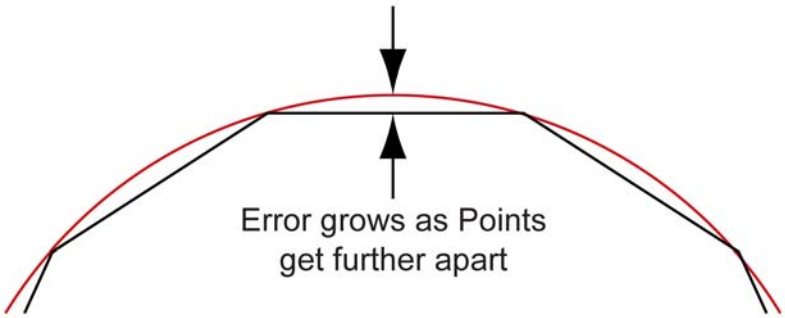


Figure 99 shows the effect of having the points too far apart on a curve lane marking. The error gets larger as the points get further apart and as the curve gets tighter. The small angle approximation for the maximum error is:

$$\frac{d^2}{8 \cdot R}$$

where d is the distance between the points and R is the radius of the curve. Table 59 shows the error for a 1 m distance between survey points on curves with different radii.

Table 59. Curve fitting error for 1 m point separation

Curvature	Maximum Error
10 m	1.25 cm
50 m	0.25 cm
100 m	0.125 cm

Unless your survey includes some curves that are tighter than 10 m radius then there is little point in surveying points with a separation less than 1 m.

The noise on the curvature depends on speed. The faster you travel, the noisier the acceleration becomes. The instantaneous error in acceleration is:

$$\frac{2 \cdot e \cdot V^2}{d^2}$$

where e is the survey error, V is the velocity of the hunter vehicle and d is the distance between the survey points.

For a 1 cm survey error on a vehicle travelling at 20 m/s (72 km/h) and a distance between survey points of 1 m the instantaneous error in acceleration is 8 m/s ². To make the acceleration acceptable a considerable amount of filtering will be required, the survey will need to be more accurate than 1 cm or the separation will need to be more than 1 m.

Rules for the Clean Up Line tool in the Map Creation Wizard

The points above, relating to the effects of the survey on the accuracy have been used to set some rules of the Clean Up Line tool. We would recommend using a point spacing of 1 m or 2 m, but the Clean Up Line tool will accept points with a separation down to 0.5 m.

For straight lines the acceleration becomes unacceptably noisy when the angle between the points exceeds about 0.5 degrees. However, this is not acceptable as a limit since a 10 m radius bend with a point separation of 1 m has a 5.7 degree angle between the lines. The limit, therefore, for the Clean Up Line tool has been set at 5.7 degrees.

Line, map and feature point file format descriptions

The line, map and feature point files are stored in text format. It is possible to generate either file using different software. A brief description of the file formats is provided here.

Line file format

The line file store each point used to mark the straight line segments during the line survey. The file is stored in CSV format and always uses the English number system (full stop for the decimal separator and comma for the list separator). Each line represents one point. The fields in the file are listed in Table 60.

Table 60. Line file format

Field	Name	Description
1	Latitude	Latitude of the point in decimal degrees
2	Longitude	Longitude of the point in decimal degrees
3	Altitude	Altitude of the point
4	Heading	Heading of the line at this point
5	North stdev[1]	Estimated accuracy of the point in the North-South direction in metres
6	East stdev[1]	Estimated accuracy of the point in the East-West direction in metres
7	Altitude stdev[1]	Estimated accuracy of the point in the vertical direction in metres
8	(empty)	Not currently used
9	# satellites	Number of satellites tracked by the GPS at this point
10	Position mode[1]	Position mode of the GPS at this point, see NCOM Description Manual for a definition of position mode.

Note 1: These fields are not currently transferred to the map file.

Map file format

The map file consists of a header, followed by each of the lines in order. An example file is shown in Figure 100.

Figure 100. Example map file

```
map number,22
origin,51.94322136,-1.26696946,138.009
start line,51.9433702331181,-1.26697457911789,51.943294365567,-1.26671038784474,Line3.rtrl,26,20
number of lines,6

line,1,Line1.rtrl
number of points,110
51.94322136,-1.26696946,138.009,027.0736,0
51.94328786,-1.26691446,138.27,026.4461,0
51.94335396,-1.26686126,138.532,025.6640,0
...

line,2,Line2.rtrl
number of points,105
51.94323215,-1.26694229,138.079,026.8682,0
51.94329884,-1.26688762,138.326,026.2888,0
51.94336506,-1.26683469,138.551,025.4278,0
51.94343107,-1.26678391,138.674,024.6603,0
...
```

Note: Not all the line information has been shown; "..." has been used to show where more information continues. There would be six lines in this file, only two are shown here.

Header fields

The fields in the header are shown in Table 61.

Table 61. Map file header fields

Field	Description
Map number	This is the map number that will be transmitted over the CAN bus and on RCOM. It is an integer number from 0 to 255.
Origin	The origin is used by the Map Creation wizard for plotting the points. It is a value of latitude, longitude and altitude near the lines.
Start line	This field describes the start line points. The sub-fields are: Left point latitude in decimal degrees Left point longitude in decimal degrees Right point latitude in decimal degrees Right point longitude in decimal degrees Filename of the line file that contains the centre of the start line Point number of the point in the line file that is the centre of the start line Width of the start line in metres Note that the start line is directional and the RT-Range will only start line tracking if the vehicle crosses the start line in the correct direction.
Number of lines	Tells the software how many lines are included in this file.

Line fields

Each line in the map file has its own header. This holds the line number, the filename used to create the line and the number of points in the line. This is followed by the line data points. Table 62 shows the fields for the line in the map file.

Table 62. Line format in the map file

Field	Name	Description
1	Latitude	Latitude of the point in decimal degrees
2	Longitude	Longitude of the point in decimal degrees
3	Altitude	Altitude of the point
4	Heading	Heading of the line at this point
5	Line Type[1]	Always zero

Note 1: The Line Type is not currently used.

Feature point file format

The feature point file holds a list of features' positions so that the RT-Range can compute the range to them. The first two lines are headers, followed by one line for each feature point. The file is stored in CSV format and always uses the English number system (full stop for the decimal separator and comma for the list separator). The feature point file should have an extension ".ftl".

The header lines in the feature point file are in the following format:

feature list,YYY,TTTTTT,NNNNNN

number of features,XXX

Table 63 gives the definitions of the fields.

Table 63. Feature point file header fields

Field	Description
Feature list	The RT-Range will use this to identify that this is a feature point file.
YYY	This is the feature point file reference number and it is output on RCOM and displayed in the Real-time Display (as "Reference number of feature set"). It can be used to identify which feature point file is being used by the RT-Range. Only an integer value from 1 to 250 can be used. Text descriptions are not supported.
TTTTTT	This field is a text description, for the user's benefit, of the feature point file. It can contain any valid alpha-numeric characters, including spaces, but it cannot contain a comma. It can be blank (i.e. two commas: ",,").
NNNNNN	This field should contain the filename of the feature point file. It is currently only for the user's benefit and it is not used by the software. The feature point file is renamed when it is saved on the RT-Range. When it is uploaded (using FTP) then this field could be used to rename the file back to its original name. This is a future potential feature that is not supported by the current software.
Number of features	The RT-Range will use this to identify this as a feature point file. If this is not the first text on the second line then the file cannot be used.
XXX	This is the number of features in the file. It can used to allocate memory space to hold the feature points as the file is read. Up to a maximum of 65530 features can be loaded.

The list of the feature points will be in the following format:

ID,Latitude,Longitude,Altitude,Heading,Type,Reserved,Description

Table 64 gives the definitions of the fields.

Table 64. Feature point file fields

Field	Description
ID	This is the ID of the feature point and it can be used to identify a specific feature point by number. It is output on the CAN bus and can be viewed in the Real-time Display. The ID should be unique in the file, but it does not need to be sequential. It is an integer number from 1 to 65530.
Latitude	This is the WGS84 latitude of the feature point in decimal degrees. It will need at least 7 decimal places (approximately 1 cm) in order to be accurate enough.
Longitude	This is the WGS84 longitude of the feature point in decimal degrees. It will need at least 7 decimal places (approximately 1 cm) in order to be accurate enough.
Altitude	This is the altitude of the feature point in metres. It is measured in the same reference system as the RT (either geoidal or ellipsoidal).
Heading	This is the heading of the feature point, which is currently not used.
Type	This is a category of the feature point that allows the user to identify what the feature point is. For example a 50 km/h speed limit sign could be assigned a type of "4", making it easier to identify when this type of sign is in view. OxTS does not have a classification of feature points and it is up to each application to categorise them. This field is an integer number from 1 to 250.
Reserved	This field is reserved and it should be set to 0.
Description	This is a text description of the feature point. It is not used by the software and it is provided for the user's benefit. It can contain any valid alpha-numeric characters, including spaces, but it cannot contain a comma.

An example feature point file is shown in Figure 101.

Figure 101. Example feature point file

```
feature list,7,RT-Range airfield test line,RT-RangeTest_AirfieldLine1.ftl
number of features,12
1,  51.94011276,-001.24408213,0130.261,258.874,1,0,X Post
2,  51.94015950,-001.24394702,0130.197,347.158,2,0,E Sign
3,  51.94024407,-001.24422378,0130.064,326.847,2,0,X1 Sign
4,  51.94039547,-001.24450395,0129.587,341.178,1,0,O Sign
5,  51.94038123,-001.24481045,0129.435,290.798,3,0,U Cone
6,  51.94049197,-001.24483301,0129.225,326.358,2,0,C Sign
7,  51.94049216,-001.24491855,0129.368,302.581,4,0,Water tap
8,  51.94044339,-001.24500736,0129.312,236.959,1,0,J Post
9,  51.94058045,-001.24540721,0129.192,247.792,1,0,8 Post
10, 51.94063415,-001.24535482,0129.209,324.338,1,0, Stick
11, 51.94078665,-001.24601052,0129.758,253.811,1,0,I Post
12, 51.94084804,-001.24595231,0129.813,341.162,1,0,6 Post
```

RT-Range and the Ibeo feature fusion ADAS reference-system

The integration of the RT-Range and RT-Range S systems with Ibeo laser scanner environment perception allows test drives in public traffic.

All relevant objects are displayed in every situation. It can be automatically determined if and how well the target vehicle is visible to an on-board sensor-under-test. Incorrect measurements on vehicles other than the target vehicle can be reliably detected. Occlusion of the target vehicle, for example by pedestrians and the like, can be reliably detected and displayed.

Introduction to the Ibeo Feature Fusion System

The Ibeo Feature Fusion is a Lidar based system. It fuses between 2 and 6 sensors mounted on the vehicle. With 6 sensors, a 360 degree view around the vehicle is possible.

The Feature Fusion System provides data such as:

- Raw distance data for each scan point containing:
  - position of the scan point
  - width (i.e. duration) of the echo pulse
  - scan layer and echo number (multi-target capability)
- Objects:
  - position of the object
  - object tracking
  - size and orientation
  - velocity
  - classification (car, bike, truck, pedestrian, unknown big, unknown small)

Benefits of adding the Ibeo Feature Fusion System to the RT-Range system

The key features of adding the Ibeo Feature Fusion System are:

1. Ibeo with RT-Range integration permits visualization of RT-Range data with Ibeo Laser View (ILV) – a very sophisticated visualization and playback tool. ILV is described in greater detail in the next section.

2. Providing information about the environment and all other vehicles. This allows data recording on public roads, not only empty test tracks.

3. Automatic calculation of visibility and occlusion of all target vehicles from the point of view of both, the laser scanners and a configurable Device under Test (DuT)

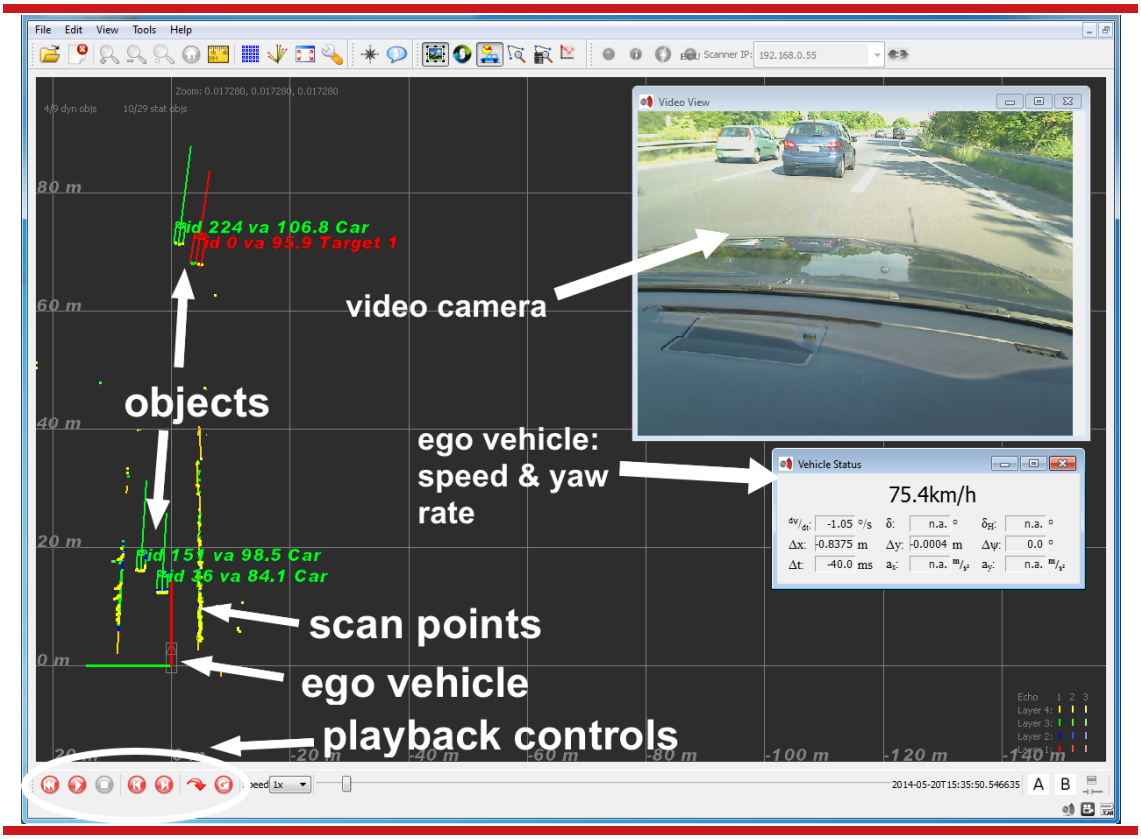
4. Blending of data from both RT-Range and Ibeo laser scanners to achieve better accuracy than is possible with either system, and to provide measurements even when the target(s) are not visible to lasers.

5. Rapid set up of RT-Range Target systems in target vehicles: utilising automatic parameter calibration and shape recognition.

Ibeo Laser View (ILV) visualization

The Ibeo visualization of a Feature Fusion System fused with an RT-Range system is shown in Figure 102. It shows the scenario from above (bird view).

Figure 102. Ibeo Laser View (ILV) data visualization



Hunter (ego) vehicle: This box shows the hunter vehicle in correct sizing and driving direction.

Scan points: Each coloured scan point represents the distance and echo pulse width (reflectivity).

Objects: The green rectangles represent all objects within the field of view of the Ibeo laser scanners with their correct sizing. Each object has the following information:

- id: Displays the objects id
- va: Absolute velocity in km/h
- classification: (car, bike, truck, pedestrian, unknown big, unknown small)

RT-Range Target objects: Targets are displayed in red and have the classification tag as 'Target *n*' where *n* represent the target number.

Hunter (ego) vehicle status. The vehicle status window provides data such as the hunter vehicle speed in km/h and hunter vehicle yaw rate.

Video camera window: The video camera window displays the recorded video image of a camera installed in the ego vehicle. This video data is not used by object tracking, its purpose is only the visualization.

For more information about the Ibeo-OxTS integration, please refer to the Ibeo-OxTS Integration Customer Documentation and the Ibeo Feature Fusion Customer Documentation which is available from Ibeo Automotive Systems GmbH http://www.ibeo-as.com/contact.html

Revision history

Table 65. Revision history

Revision	Comments
051018	Initial Version
051114	Typing Corrections
051118	More Corrections and change of CAN IDs to 7A0h/7B0h range
060803	Updated for new RT-Range box
061211	Software changes
070611	Software changes
071214	Software change. Logging added; Longitudinal Offset added; Wireless LAN SSID and IP Address added
080613	Added multiple Targets
081212	Added Fixed Point from RT; Post-processing measurements from Targets. Changed packing lists for new Wireless LAN antenna.
090619	Removed optional SATEL radio. Added ABD robot connection. Survey Trolley Installation moved and improved. Clarified workflow for post-processing. Added Line File and Map File formats. Changes for the latest software.
090917	Added Survey Trolley Assembly section.
100426	Added velocity compared to lines; time gap. Added lateral offsets. Added maps in Bird's Eye View. Changed RCOM logging. Added RT2000 product references.
110228	Added polygons; hidden targets; hunter measurement plane; target status on CAN bus; range accuracy outputs; lane heading and curvature; additional lane measurements from points B/C; lane heartbeat message; start line in logging window.
121121	Corrections to CAN messages (default identifiers, offsets and description). Added fixed point heading and feature point ID, type, position and heading to CAN outputs. Updated software screenshots and description to include feature points, fixed point polygons. Added description about adding multiple line files. Changes to Configure Display.
131210	Increased polygon points to 24. Updated ABD robot interface. Increased field of view range to 500 m. Added CAN pin assignments. Other minor updates.
140611	Modified to incorporate RT-Range S system. Wiring, configuration drawings, specification changes and conformance notices.
140802	Updated with information about the Ibeo fusion system. Added move table scaling.
141202	Updated for real-time CAN acquisition. RT-Range front panel connections, new images and other minor revisions.
151010	Added Hunter polygon, added new acceleration filters, updated styles, GUI updates.